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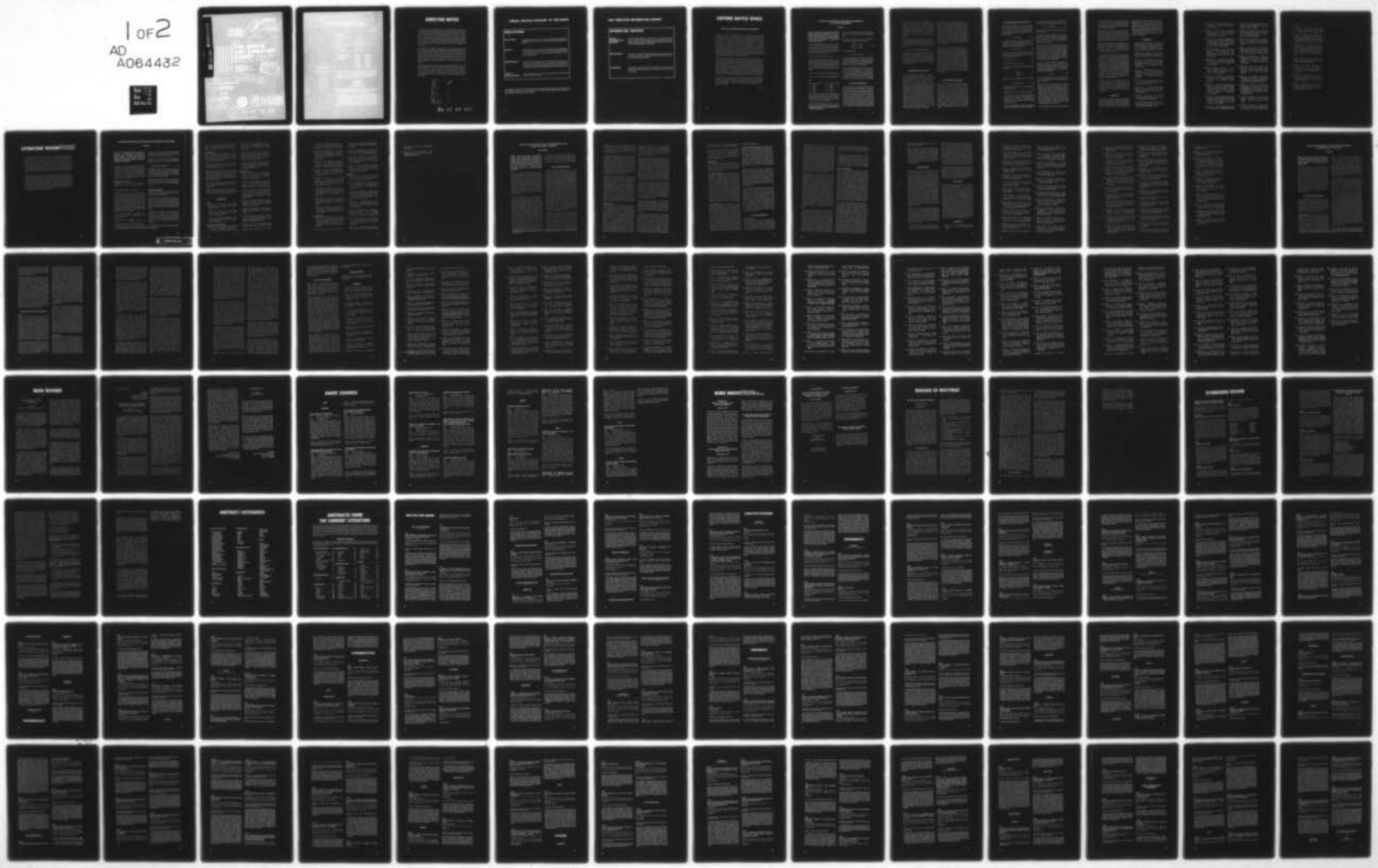

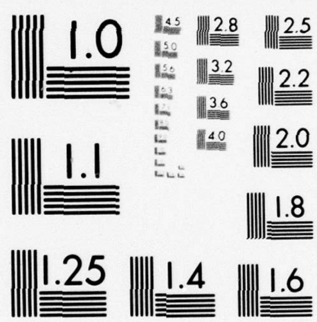

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Judith Nagle-Eshleman

Shock and Vibration Information Center
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THE SHOCK AND VIBRATION DIGEST

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THE SHOCK AND VIBRATION INFORMATION CENTER

Code 8404, Naval Research Laboratory
Washington, D.C. 20375

Henry C. Pusey
Director

Rudolph H. Volin

J. Gordon Showalter

Barbara Szymanski

Carol Healey

The Shock and Vibration Digest is a monthly publication of the Shock and Vibration Information Center. The goal of the Digest is to provide efficient transfer of sound, shock, and vibration technology among researchers and practicing engineers. Subjective and objective analyses of the literature are provided along with news and editorial material. News items and articles to be considered for publication should be submitted to:

Dr. R.L. Eshleman
Vibration Institute
Suite 206
101 West 55th Street
Clarendon Hills, Illinois 60514

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DIRECTOR NOTES

The reader will note a brief description of a forthcoming SVIC publication on international shock and vibration technology on the inside back cover of this issue. This survey was a significant undertaking involving all members of the SVIC staff. I wish to thank Rudy Volin, Gordan Showalter, Barbara Szymanski, and Carol Healey for the dedication and hard work that made this publication possible. Thanks are also due to Ron Eshleman for his constructive suggestions and assistance, and to my wife, Sallie, for her volunteer work at home. In the future we plan to continue to look closely at international information needs with the hope for providing a catalyst for the proper balance of international competition and cooperation.

The 49th Shock and Vibration Symposium was a clear success. The readers may note the review in this issue. My sincere appreciation is extended to NASA Goddard Space Flight Center and Dr. Robert S. Cooper, Director, for their excellent cooperation as Host. Dr. Cooper's welcome was most sincere and inspiring. My particular thanks to Brian Keegan of Goddard Space Flight Center for arranging the outstanding local support. Mr. Stofan of NASA Headquarters and the three invited speakers provided an excellent opening session. We look forward to another outstanding symposium in October 1979 with the U.S. Air Force as Host in Colorado Springs.

Beginning with the next issue this column will be headed SVIC NOTES. I feel that other members of the staff at the Shock and Vibration Information Center should have an opportunity to pass along their thoughts regarding SVIC operations in particular and the technology in general. I, of course, will continue to write an occasional column. We will also include significant SVIC news and announcements when appropriate. For now, let me wish each and every reader a Happy and Prosperous 1979.

H.C.P.

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the Center handles requests for information via mail, telephone, and direct contact. The Center technical specialists, who are experts in the shock and vibration field, have the SVIC computer implemented SHOCK AND VIBRATION INFORMATION BASE at their disposal.

WORKSHOPS

workshops on shock and vibration technology are organized and sponsored by the Center. Experts on specialized technology give lectures and write articles for the workshop proceedings.

SYMPOSIA

annual shock and vibration symposia bring together working scientists and engineers for formal presentations of their papers and for informal information exchanges.

EDITORS RATTLE SPACE

THE BALANCE BETWEEN THEORY AND PRACTICE

During a recent course on vibrations some of the participants complained about the quantity of "theory" presented. "Theory" included both physical descriptions and mathematical analysis of vibrations. That many practicing engineers share this attitude is not news to me. Some engineers apparently cling to the fallacy that any vibration problem can be solved by the "cookbook method" -- matching the problem to a similar case history that has been published in the literature. Although I firmly believe that a person learns from case histories, I know that many vibration problems cannot be solved by comparing them to case histories or placing them in some neat solution category. Vibration problems typically are unique because an almost infinite number of possibilities for trouble exist: complicated structures, foundations, bearing supports. For these reasons some theory must be mixed with practice -- if only to provide the engineer with a better understanding of what is happening in the machine or structure.

On the other hand, theory must be tempered with practical knowledge. The use of theory alone to solve vibration problems will undoubtedly lead eventually to a complete disaster. Mathematical descriptions of vibrating objects are at best incomplete. The complexity of most real vibration problems defies detailed description by mathematics; however, some understanding of the physics can be obtained by the engineer who can think in terms of simple mathematics. Mathematical models that describe the important aspects (structural or functional failure related) of a vibration problem are tools that should not be overlooked. Mathematical models provide physical understanding as well as quantitative information. Such information should compliment observations, measurements, and signal analysis.

In my opinion, therefore, no powerful tool should be overlooked or neglected in attempts to solve vibration problems. It is likely that a nasty and persistent problem will force the engineer to use all the tools available. If he bypasses some tool -- practical or theoretical -- he prolongs his difficulties and possibly never finds a solution to his problem.

R.L.E.

EVALUATION OF STIFFNESS AND DAMPING COEFFICIENTS FOR FLUID-FILM BEARINGS

J.W. Lund*

*Abstract - **Methods for calculating fluid film bearing stiffness and damping coefficients are briefly described. Restrictions imposed by such assumptions as linearity are evaluated. Experimental methods used to obtain data necessary to determine the coefficients are presented.***

In analysis and design calculations in rotor dynamics, it is common to model fluid-film bearings as dynamic systems with linear stiffness and damping properties. From lubrication theory the bearing reactions are functions of the journal center coordinates, x and y, and the associated velocities, $\dot{x}$ and $\dot{y}$.

$$R_x = R_x(x,y,\dot{x},\dot{y};S) \quad R_y = R_y(x,y,\dot{x},\dot{y};S) \tag{1}$$

The dimensionless Sommerfeld number, S, serves to define the operating conditions (speed, lubricant viscosity, static load, geometry). At any particular static equilibrium position with coordinates x_o and y_o, to which belongs a unique value of S, a first order expansion of the reaction forces can be employed.

$$\Delta R_x = R_x - R_{xo} = K_{xx}\Delta x + K_{xy}\Delta y + B_{xx}\Delta\dot{x} + B_{xy}\Delta\dot{y}$$
$$(2)$$
$$\Delta R_y = R_y - R_{yo} = K_{yx}\Delta x + K_{yy}\Delta y + B_{yx}\Delta\dot{x} + B_{yy}\Delta\dot{y}$$

where

$$R_{xo} = R_x(x_o,y_o,0,0;S) \qquad R_{yo} = R_y(x_o,y_o,0,0;S)$$
$$K_{xx} = \left(\frac{\partial R_x}{\partial x}\right)_o \qquad B_{xx} = \left(\frac{\partial R_x}{\partial \dot{x}}\right)_o \tag{3}$$
$$K_{xy} = \left(\frac{\partial R_x}{\partial y}\right)_o \qquad B_{xy} = \left(\frac{\partial R_x}{\partial \dot{y}}\right)_o$$

and similarly for the remaining coefficients. The coefficients that are evaluated for a particular static equilibrium position become functions of the Sommerfeld number. This means that for a given application, they are functions of rotor speed.

It should be added that equation (2) in a more complete form also contains four acceleration coefficients. They represent the virtual mass of the bearing film [10] but are significant only in exceptional cases.

By adopting frequency domain representation, equation (2) can be written in matrix form.

$$R = \begin{Bmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{Bmatrix} X \tag{4}$$

The Zs are impedances.

$$Z_{xx} = K_{xx} + i\omega B_{xx} \tag{5}$$

For gas bearings [8] and such bearing types as pivoted pad bearings [5] or floating ring bearings, the real and imaginary parts of Z become frequency dependent. This implies that the stiffness and damping coefficients are functions of frequency.

The damping coefficients are symmetric ($B_{xy}=B_{yx}$), but the stiffness coefficients are not ($K_{xy} \neq K_{yx}$). Therefore principal directions do not exist. Thus, in an experimental determination of the coefficients, it is necessary to obtain two independent sets of amplitude-force measurements. R and X in equation (4) become 2 by 2 matrices, which are complex.

CALCULATION METHODS

Several methods for calculating the stiffness and damping coefficients have appeared in the literature. In one method some form of an approximate analytical solution of the lubrication equation (Reynold's equation) is derived; the coefficients are then obtained by partial differentiation [7, 9]. The method is cumbersome, and its use has been limited to plain cylindrical bearings, particularly short ones. Alternatives are the many available numerical solutions of Reynold's equation. The coefficients are obtained by simple numerical differentiation and computed from the change in forces caused by small but finite

Department of Machine Elements, Technical University of Denmark, Lyngby, Denmark

increments in journal center coordinates and velocities [2, 4, 6]. It is difficult, however, to assure satisfactory numerical accuracy, especially at small eccentricity ratios. This difficulty also exists with the method in which the stiffness coefficients are calculated by differentiating the static equilibrium locus [19]. This method is also restricted to an axisymmetric geometry; i.e., the plain cylindrical bearing.

The coefficients can be obtained as true gradients using a perturbation solution for equation (3) [1, 3, 8]. The steady-state bearing-film pressure p_o is given a small perturbation Δp. The resulting pressure p becomes

$$p = p_o + \Delta p = p_o + p_x \Delta x + p_y \Delta y + p_{\dot{x}} \Delta \dot{x} + p_{\dot{y}} \Delta \dot{y} \qquad (6)$$

Substitution into Reynold's equation results in five partial differential equations, one for each of the five pressure components. Because the equations have a common operator, they can readily be solved by available numerical techniques. The coefficients can then be computed by integration of individual pressure components.

ASSUMPTIONS IN THE ANALYSIS

From a theoretical point of view, the expansion of the bearing reactions by coefficients is valid only for infinitesimal amplitudes. The forces are actually highly nonlinear functions of their arguments -- especially the journal center coordinates -- but, because the forces always increase with increasing eccentricity, their replacement by linear coefficients is equivalent to replacing a hardening-softening spring characteristic with a mean gradient. This gradient is sufficiently accurate for most cases of interest. For light- and medium-loaded bearings (eccentricity ratios up to ½), the linearized coefficients apply for amplitudes as large as 50 percent of the clearance, a range that is less than 10 percent for higher bearing loads; that is, eccentricity ratios in excess of 0.7 [9, 30]. It should be mentioned that, as the journal whirl orbit increases, its center no longer coincides with the static equilibrium position but moves gradually closer to the bearing center. This movement does not affect the dynamic amplitude.

The restrictions on the theory imposed by the assumption of linearity are not necessarily the most serious ones. For example, the solution of Reynold's equation is usually based on the assumption of isothermal conditions with a known film temperature (viscosity). This temperature is often difficult to predict. In addition, some hypothesis governing the mechanism of film rupture might not be adequate under dynamic conditions. There is also a largely unknown effect from oil supply pressure and oil supply conditions in general. Finally, the coefficients may be quite sensitive to manufacturing tolerances [11] and alignment.

The significance of these problems has been illustrated in numerous tests on the performance of bearings under static load conditions; examples have been published [12-15]. As a rule appreciable differences are common between theoretical predictions and experimental results, not only in the shape of the static equilibrium locus but also in the correlation between Sommerfeld number and journal eccentricity. Thus, for two reasons -- the dynamic coefficients depend directly on the static equilibrium position and the stiffness coefficients are strongly related to the shape of the locus curve -- there seems need for additional improvements in the lubrication analysis rather than further refinements in the dynamic analysis.

DATA FOR THE COEFFICIENTS

Few data are available in the accessible published literature for the dynamic coefficients for bearing types used [1-4, 6, 26]. Because such data are required in rotor dynamics calculations, existing demands are far from being met. In addition, the large number of bearing types, each having several geometrical parameters, makes difficult the task of covering the range of application. Furthermore, tables of coefficients require interpolation, so that reasonably close spacing in the data points is necessary for accurate results, and much more data, and consequently large tables, are required. Many users therefore prefer to have access to a computer program to generate data tailored to their particular needs.

MEASUREMENTS OF THE COEFFICIENTS

Experimental determination of the coefficients necessitates accounting for the impedance of the rotor. The vector of measured rotor amplitudes X_m is related to the vector of applied forces F and the generated bearing support forces S by the matrix equation.

$$X_m = G_1 S + G_2 F \tag{7}$$

The impedance matrices G_1 and G_2 belong to the free shaft. They can be calculated or sometimes measured. An analogous equation applies at each bearing such that for bearing number n

$$X_n = H_{1n} S + H_{2n} F \tag{8}$$

When the number of amplitude measurement locations equals the number of bearings, the equations have the solution shown below.

$$S = G_1^{-1}\,[X_m - G_2 F] \tag{9}$$

$$X_n = H_{1n} G_1^{-1}\,[X_m - G_2 F] + H_{2n} F \tag{10}$$

The vector S is made up of the individual bearing reactions R_n.

$$S = \left\{ \begin{matrix} R_1 \\ \vdots \\ R_n \end{matrix} \right\} \tag{11}$$

Hence R_n can be expressed by means of equation (9).

$$R_n = G_n [X_m - G_2 F] \tag{12}$$

Equations (4), (10), and (12) can be combined to yield equation (13).

$$Z_n \left\{ H_{1n} G_1^{-1} [X_m - G_2 F] + H_{2n} F \right\} = G_n [X_m - G_2 F] \tag{13}$$

Z_n is the 2 by 2 matrix of bearing coefficients; see equation (4). The equation can be solved for Z_n when there are at least two independent sets of measurements, X_m, produced by two independent sets of applied forces F.

Most test rigs are designed to measure the coefficients directly and have only a single test bearing. The bearing floats on a rotating shaft [15, 17-20, 24-26]. In that case equation (13) reduces to equation (14).

$$Z_n X_m = \omega^2 M X_m + F \tag{14}$$

M represents the mass of the bearing housing, and ω is the frequency.

This design has many advantages, one of which is the ease by which the static load and the applied force can be varied. The tests referenced differ somewhat in the choice of forcing type, although all employ harmonic forces.

Test results confirm the general validity of the theory, but is is not unusual to find discrepancies of 50 percent or more in a point-by-point comparison. It is difficult, however, to analyze the degree to which the results may be affected by measurement tolerances and by uncertainties in establishing test parameters. The last is especially true when -- as is usually the case -- the measured static locus does not coincide with the theoretical one.

It is also possible to measure the coefficients of bearings in a rotating machinery application. Such measurements require, as shown by equation (13), that the shaft impedances be known. The relationship between the applied forces and the measured amplitudes can be expressed.

$$X_m = G_3 F \tag{15}$$

After G_3, a transfer matrix to be determined from tests, is obtained, equation (13) can be solved for the bearing coefficients.

Because of the practical difficulties of exciting a rotating shaft by an external harmonic force, a method has been developed to obtain the transient response from snapping a loaded strap [16]. G_3 is then determined by Fourier transform analysis. Problems arise in determining the time history of the force and in eliminating noise and residual synchronous response, but the results look very promising. Similar problems would be expected to arise with another method, in which a random excitation is used to obtain the transfer matrix from cross-correlating response and force [33].

From a practical point of view, the simplest method

is to use an unbalance force as excitation. As seen from equation (13), this would require tests with a minimum of two dissimilar unbalance distributions; such a distribution is readily done. Thus far, however, the method has not been used.

Measured values of spring and damping coefficients have been calculated on the basis of measured unbalance response whirl orbits [21-23], but the cross-coupling coefficients are ignored. The results therefore represent some form of effective rotor-bearing coefficients and not the true film coefficients.

Damping coefficients have been measured in the special case of squeeze-film dampers which are equivalent to bearings with a nonrotating journal [27, 28]. The results, in general agreement with theoretical predictions are sensitive to conditions of oil supply and film rupture.

In many tests with rotors and machinery measured response has been compared with calculated response. Because the calculations are based on theoretical values for the bearing coefficients, they serve as an indirect check on the theory, and agreement is usually satisfactory. Theoretical whirl amplitudes and phase angles compare well with experimental values [29, 30, 32], at least for engineering purposes. Good correlation has also been found [31, 32] in the case of measurements of the dynamic film pressure, calculated from equation (6). There are indications, however, that the unbalance response of a rotor frequently is not very sensitive to deviations in the values of the bearing coefficients.

A more critical test is the determination of the threshold of instability [6, 17, 34]. The onset of self-excited whirl is often ill defined, however, and the possible influence from extraneous damping may be difficult to assess. Even so, tests tend to confirm the validity of the theory within the experimental tolerance band.

CONCLUSIONS

The method by which the dynamic characteristics of fluid-film bearings can be represented by linearized stiffness and damping coefficients (or impedances) has been well established by tests and analysis. A stage in the development of the state of the art has been reached in which improvements and further investigations are needed. First, a better understanding of the fundamental behavior of bearings is required. There seems little point in refining dynamic analysis until better agreement between theory and measurements has been obtained on the performance of static bearings. On the other hand, the existing methods and data are sufficiently accurate for most practical design purposes.

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LITERATURE REVIEW

survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains review articles on parameter identification techniques for vibrating structures, noise characteristics of axial and centrifugal fans as used in industry and finite element modeling of structural vibrations. A brief description of mathematical formulations of a vibrating structure is presented by Mr. Alex Berman of Kaman Aerospace Corporation. Basic noise generating mechanisms, fan noise prediction techniques, and noise reduction techniques are discussed by Mr. Mugridge of British Gas Corporation. Professor Reddy of the University of Oklahoma reviews research in the finite element modeling of structural vibrations including beams, plates, and shells.

PARAMETER IDENTIFICATION TECHNIQUES FOR VIBRATING STRUCTURES

A. Berman*

Abstract - A brief description of mathematical formulations of a vibrating structure is presented. Several categories of parameter identification are described. Related works published in the past several years are categorized. Surveys covering earlier contributions are referenced.

The majority of the work in parameter identification techniques carried out since 1975 has been related to improvements in applying techniques that have been in existence for a number of years. Validated and generally accepted techniques for the experimental determination of the structural parameters of vibrating structures are not available. Considerable basic research in this area is needed.

Mathematical Formulations

The common time domain discrete formulation of the equation of motion of a linear vibrating structure is

$$[M]\{\ddot{x}_i\} + [C]\{\dot{x}_i\} + [K]\{x_i\} = \{f_i\} \qquad (1)$$

where $[M]$, $[C]$, $[K]$ are the familiar mass, damping, and stiffness matrices; $\{x_i\}$ is a vector of the physical degrees of freedom; and $\{f_i\}$ is a vector of the forcing functions. Nonlinearities may appear in the matrices or as additional terms in the equation. These equations are often written as a set of first order equations in the state variables. The coefficient matrices are not directly measurable [2]. If these differential equations are solved using specific forcing functions, the resulting solution vectors $\{\ddot{x}_i\}$, $\{\dot{x}_i\}$, and $\{x_i\}$ are measurable quantities.

If the forcing is assumed to be sinusoidal at a frequency ω, the equation is transformable to the frequency domain

$$\left[-\omega^2 [M] + i\omega[C] + [K]\right]\{x_i\} = \{f_{\omega i}\} \qquad (2)$$

The matrix on the left is an impedance type matrix. Its inverse is a mobility matrix, and each element is a transfer function. These elements are measurable and represent the response of each point on the structure to a sinusoidal force at each point.

Equation (1) may be transformed into an undamped eigenvalue problem by setting $\{f_i\}$ and $[C]$ equal to 0

$$-\omega_i^2 [M]\{\psi\}_i + [K]\{\psi\}_i = 0 \qquad (3)$$

where $\{\psi\}_i$ is the ith normal mode, and ω_i is the corresponding natural frequency. The normal modes and natural frequencies are classified as measurable [2] even though special processing of test data is required in order to identify them.

The matrices of equation (1) and the impedance and mobility matrices (or transfer functions) of equation (2) can be expressed in terms of these modal parameters [2].

Parameter Identification

The process of using test data to identify or correct the elements in any of the above equations is called parameter or system identification.

When identification of the physical characteristics of the structure is desired, a method for determining the elements of the coefficient matrices of equation (1) must be used. Such a method is necessary in order to establish a baseline analytical model when physical changes or boundary condition changes are to be studied.

Identification of impedance or mobility matrices, equation (2), can be used to study the effects of various forces on the structure or for a component synthesis analysis. When response at specific locations in the structure is desired, individual elements of the mobility matrices or transfer functions must be identified.

The identification of modal parameters, equation (3),

* *Principal Research Engineer, Kaman Aerospace Corporation, Bloomfield, Connecticut*

is used for general validation of an existing analytical model, for component synthesis, or to form impedance and mobility matrices in a series form.

Literature Review

An ASME publication [1] contains several discussions of techniques and applications of system identification and numerous references to past works. Other surveys [2, 3] also contain many useful references published before 1975.

A relatively small amount of work has recently been published related to the direct identification of mass, damping, stiffness matrices [4-7].

The majority of structural parameter identification research and applications has been in the area of modal parameters [8-22]. This is partly due to the new families of equipment and software that have become available in the past several years for determining these parameters.

Work related to the determination of transfer function or mobility representations has also been published [23-27].

Finally, several papers have emphasized such considerations as correlation of test data, nonlinear system parameters, and distributed parameters [28-35].

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NOISE CHARACTERISTICS OF AXIAL AND CENTRIFUGAL FANS AS USED IN INDUSTRY - A REVIEW

B.D. Mugridge*

Abstract - This review is aimed at the industrial engineer. Basic noise-generating mechanisms are reviewed. Overall fan noise prediction techniques are discussed. Various techniques that have proved useful for reducing noise at the source are described. The specialized reader will find references to some of the more recent contributions -- including those for high-speed machinery -- that have been published since 1975.

Most of the research into sound generated aerodynamically, particularly by rotating blades, has been associated with developments in the aircraft industry. The initial interest was in the sound radiated by propeller blades, but recently the main effort has been directed toward understanding both the fan and jet noise of turbomachinery. Axial flow fans have therefore been studied in depth, and the basic noise generating mechanisms are now well established. The number of published papers continues to grow, adding to theoretical knowledge and providing further experimental evidence of the suitability of theoretical models.

In 1973, Morfey [1] wrote an excellent review paper on rotating blade noise and aerodynamic sound. More recently, Cumpsty [2] presented a critical review of turbomachinery noise, including the more important papers published prior to 1977. Study of the two papers suggests that the progress achieved in aeronautics has not yet been fully exploited in the general engineering industries. One reason is the limited financial resources available for applied research and development programs. It is an unfortunate situation because fans are a major source of noise in mixed industrial-residential areas. In a recent survey of the noise levels at the boundaries of factories and commercial premises, it was shown that more than 50 percent of 70 identifiable noise sources were due to either supply or extract fans or compressor systems [3]. This situation is not acceptable: although research will never eliminate all noise sources, the knowledge and experience gained thus far should be sufficient to reduce most of the annoying components of the radiated noise spectrum. The reason is that the lower blade loadings and tip speeds of conventional industrial fans eliminate some of the more complex sound-generating mechanisms experienced with aircraft engines.

BASIC NOISE MECHANISMS

In 1918 Lanchester recognized that the major source of propeller noise was the steady rotation of the blade force field. This source was subsequently examined by a number of investigators; Gutin [5] determined the amplitude of the radiated sound as a function of the steady loading of the propeller. Lighthill's [6] general theory of the sound generated by turbulent flow was extended by Curle [7], who demonstrated theoretically that the interaction of an unsteady flow field with a rigid surface produced surface pressure fluctuations that could be considered the origin of a more efficient noise source. A fan or helicopter blade rotating in free space (or in a duct) was thus shown to radiate noise from both the steady and fluctuating lift forces [8]. Steady loading on the rotor blades was confirmed [9], as were the following: that any periodically induced unsteady loading would generate a discrete frequency noise spectrum and that any randomly induced force field -- for example, that due to the interaction of the blade with turbulent flow -- would produce a broadband noise spectrum. These concepts helped to explain the observed noise spectrum characteristics of an axial flow machine, fan, or propeller.

Prediction of the amplitude of total radiated sound depends on an accurate assessment of the unsteady flow to blade interaction. Curle's hypothesis of an acoustic dipole source related to surface force fluctuations is the most easily understood source model, but it is also possible to consider the direct radiation of the turbulent flow field whose acoustic properties are radically altered by the presence of the immersed solid surface. Turbulence is a relatively inefficient radiator of sound because the phasing between

**British Gas Corporation, Research & Development Division, Midlands Research Station, Wharf Lane, Solihull, West Midlands B91 2JW, UK*

individual components of the flow field tends to be self canceling. The effect of inserting a solid surface into this flow is scattering, which reduces this cancellation and therefore causes an increase in the radiation efficiency [10].

The scattered turbulence concept is useful in calculating the noise radiated from the blade trailing edge, but it is often more convenient to use the acoustic dipole model because the surface pressure distribution is more readily measured and the sound radiation computed. Under some conditions the pressure field can be calculated. If the fan blade chord is less than the acoustic wavelength, the surface pressure distribution caused by the interaction of the blade with a convected nonuniform flow can be calculated from unsteady airfoil theory.

Generalized formulas for unsteady lift in incompressible flow have been obtained [11]. This work was extended to include the effects of blade span and fluid compressibility. One recent contribution on compressibility effects can be used to determine the fluctuating force on a fan blade for both periodic and random flow disturbances [12]. The response of complete blade rows to upstream flow disturbances has been studied [13-15], as has the interaction of stream-wise gusts with airfoils of finite thickness [16]. One or more of these theoretical models can be used to calculate the unsteady blade forces. Inserting these forces and a spanwise correlation length into Curle's basic equation gives the source strength, from which radiated sound levels can be computed.

Rotational Noise

The steady thrust force on a propeller blade radiates sound because it accelerates relative to the observer. On a multi-bladed rotor disc the radiation process is inefficient because the force pattern rotates at subsonic speed. For equally spaced rotor blades the sound occurs at the blade passing frequency and its harmonics. When the rotor operates in a disturbed velocity field -- for example, the wake flow from a stator row -- the rotating blades experience periodic forces. If the stationary blade row consists of V equally spaced identical vanes, the rotor force field at the blade passing frequency contains components that rotate at B/(B-sV) times the rotor speed, where s is any integer positive or negative [17]. Thus, if sV is close to the blade number B, part of the force field can rotate supersonically even when the rotor speed is well below sonic. It is well known [18] that there is a rapid increase in the radiated sound power when the acoustic mode, m=B-sV, begins to rotate supersonically. It is for this reason that periodic force fluctuations are the major contributors to discrete tone noise of fans.

The distortion mode sV can be considered as the λth harmonic of any spatial inlet flow nonuniformity that generates the λth loading harmonic on any rotor blade. At the rotational frequency $n\Omega$, there may be a number of loading harmonics λ that contribute to the radiated sound waves. In fact the number of contributing harmonics increases as the fan speed Ω increases. Under some conditions one loading harmonic can contribute to more than one rotational harmonic. For equally spaced rotor blades all the sound waves cancel except at multiples of the blade passing frequency. The tones are often heard as a sharp whistling sound that can be very annoying.

If the dominant interaction is that of a stationary blade row with a rotating flow distortion -- typically produced by the upstream rotor wake flow -- each loading harmonic is given by a wake harmonic and corresponds to a sound harmonic [19, 20]. The total radiation from the stator row at a sound harmonic (e.g., λ = nB) then depends on the contributions from all stator blades. This total sound can be reduced by judicious unequal circumferential spacing of adjacent stator blades [21].

The techniques for reducing noise from rotor-stator interactions are well established. The axial spacings between rows must be at least one chord in order to reduce the strength of the interaction, and the blade numbers must be chosen to give a high mode number m, to take full advantage of its reduced radiation efficiency.

It is more difficult to reduce the tone noise caused by interactions of the rotor with an inlet flow distortion field because a free choice of the loading harmonics λ is not possible. Some recent experiments on the importance of inlet flow distortion noise compared with other impeller interactions have been described [22-25]. One method of reducing the intensity of this type of interaction -- assuming that the flow distortion itself cannot be controlled -- is to unequally space the rotor blades. This alters the preference for radiation at the blade passing

frequency at the expense of additional radiation at other multiples of the shaft rotational frequency.

Unequal spacing is sometimes particularly effective at low shaft speeds, but, if the inlet flow field is distorted, the multiplicity of loading harmonics λ provides a spectrum rich in rotational harmonics in which the dB(A) rating is often no better than the original equally spaced rotor.

Broadband Noise

The most common sources of broadband noise in fans are interactions between the blades and oncoming turbulent flow, the effects of the blade turbulent boundary layers, and the influence of the blade to duct tip clearance.

Tip clearance effects. Little is known about tip clearance noise although the author did determine that the noise radiation from this source was influenced by the three-dimensional flows induced by the blade loading, tip clearance, and duct boundary layer thickness [26]. More recently Longhouse [27] investigated the possibility of reducing tip vortex noise by fitting rotating shrouds on axial fan impellers. A noise reduction of up to 12 dB was obtained with properly contoured rotating shrouds compared with a standard fixed shroud system. Other measurements of the noise generated by the impingement of outer wall and hub-induced boundary layer turbulence with an axial flow impeller have been described [28]. This work has been extended to include the interaction of inlet guide vane secondary flows with a downstream rotor [29].

Inlet turbulence noise. Inlet turbulence noise can be calculated using unsteady lift theory for the fluctuating force strength. The main differences between this turbulent flow model and the periodic interactions mentioned above are the spectral distribution of the upstream flow field and the magnitude of the span-wise correlation length of the induced forces. A theoretical treatment of this problem has been published [30], and experiments in which both the intensity of inlet turbulence and the radiated noise were measured for a subsonic axial flow fan have been described [31]. In a more fundamental study of the noise generated by the impingement of turbulent flow over airfoils, cylinders, and other flow obstructions, Olsen [32] concluded that the basic available theories give fairly accurate estimates of the measured noise spectra.

Turbulent boundary layer noise. Turbulent boundary layer noise is less easily predicted than inlet turbulent noise. One technique combines Curle's analysis and measured boundary layer pressures. Alternatively the scattered turbulence model previously discussed can be used if the strength of the turbulence in the vicinity of the blade trailing edge is known or can be estimated. Archibald [33] has published some interesting data on a possible mechanism whereby the sound field is controlled by a boundary layer flow instability that is driven by an acoustic feedback loop.

Current interest in this aspect of blade noise is reflected in the number of papers published in the past three years. Generalized formulas for predicting the rotor wake-induced sound power for low tip speed axial fans [34, 35] support earlier work which emphasized the importance of the boundary layer thickness and wake width on overall noise levels. Detailed studies of the boundary layer-induced turbulence and the radiated noise spectra from airfoils are available [36].

On the theoretical side, Amiet [37, 38] calculated the relative importance of trailing edge noise compared with inlet turbulence effects and concluded that the latter is more important. Longhouse [39] studied the case of vortex shedding tone noise. This mechanism is unusual in the sense that it is not usually present in axial flow impeller noise in which the inlet turbulence or blade pressure gradients destroy the laminar boundary layer condition necessary for the generation of coherent vortices. In fact the condition was measured only with lightly loaded rotors. However, the paper is of interest because it is an attempt to analyze the instability condition discussed by Archibald [33].

FAN NOISE PREDICTION

Axial Flow Fans

Fan noise data should always be examined in terms of the separate flow mechanisms just described because the type of fan installation can have a marked effect on radiated sound. For example, a prediction of the sound power of axial fans tested in standard ducted calibration test rigs having downstream

throttling would seriously underestimate measured data if the fans were installed in a highly turbulent or distorted flow field. This can happen in ventilator duct systems with cooling fans and in automotive cooling systems. If the unsteady flow conditions are known, the radiated power from each mechanism for each installation can be predicted with fair accuracy. One method of tackling this problem has been described [4]. Alternatively, for a given environment it can be assumed that the unsteady flow quantities vary predictably with the steady flow conditions and that the sound power can be written in terms of fan pumping capabilities and the nondimensional pressure and flow coefficients. Clearly the proportionality constant would be different for major changes in the operating environment.

Several analyses of broadband noise have been published. Mellin [40] showed that the residual broadband noise of a single axial rotor can be expressed in terms of the flow coefficient. More recently Longhouse [41] showed that varying the flow coefficient of an isolated rotor by flow control changes the relative contributions of tone and broadband noise components to the overall spectrum. The tonal components, caused mainly by flow distortions, dominated the noise spectrum at high flow coefficients (low disc loading); the broadband noise became dominant at low flow coefficients (high disc loading). In particular the exponent of noise versus rotor tip speed was mechanism dependent. This means that, as the fan operating point moves along the flow coefficient-pressure coefficient curve of a particular blade design, the sound power law varies from the sixth power of relative blade velocity to some other power value, which could be as low as 4.5.

Using this approach Mugridge [4] attempted to derive theoretical expressions for the overall broadband sound power of axial flow industrial fans based on the fundamental models previously described but written in terms of the basic fan parameters pressure, volume flow, static efficiency, and both pressure and flow coefficients. These parameters encompass speed and size effects and can also be combined to give power consumption. The results were expressions of proportionality between the spectral sound power and the fan parameters. These equations were applied to the noise of cooling fans used in heavy automotive vehicles [42]. Hawes [43] obtained a similar result for the overall sound power of automotive fans but expressed the data as a function of horse power input, tip speed, and fan diameter.

The prediction of blade passing frequency noise for rotor-stator interactions can be carried out with reasonable accuracy in another way [21]. Interactions between a rotor and an inlet flow nonuniformity should be analyzed for each situation. In most cases the blade passing tones can be predicted with fair accuracy using line dipole theory [44-46].

Centrifugal Fan Design

Very little work has been done on the aerodynamic noise of centrifugal fans and blowers even though they are used extensively in heating and ventilating plants. They operate at low Mach numbers and have impeller configurations susceptible to partial stall; thus, most of the sound power is generated in the lower frequency bands and is influenced by the acoustic reflection properties of the inlet and outlet ducts and the impeller housing. The discrete frequency tone at the blade passing frequency is primarily the result of aerodynamic interaction between the impeller wake flow and the volute cutoff. Neise [47] collated data demonstrating the importance of both cutoff spacing and radius and cutoff or impeller inclination on the magnitude of the blade passing tone. In typical industrial fan design this tone is about 5 dB higher than the broadband noise level within the appropriate octave band (usually 500 Hz).

It is not always clear whether the broadband noise is created predominantly within the impeller or the volute because the velocity distribution varies considerably with different fan designs. The forward curved bladed centrifugal impeller acts mainly as a momentum-gaining device and relies on the volute for efficient conversion of the high kinetic energy into useful pressure energy. In backward curved bladed fans most of the useful work occurs in the impeller itself, the volute acts basically as a collector. Fortunately it is somewhat easier to derive a broadband sound power law for the centrifugal fan than for the axial type because the flow pattern within the centrifugal design is often determined by the housing and impeller geometry and is not too sensitive to upstream flow turbulence. The exception is highly throttled fans in which the damper is located immediately adjacent to the fan housing. Except for the

last condition the broadband noise output can be realistically predicted [4].

More recent work on centrifugal fan noise has been described [48-52]. Deeprose [48] gives sound power estimates for both axial and mixed flow fans as well as for centrifugal pumps. Both Challis [49] and Bartenwerfer [50] discuss experimental evidence of the basic noise generating mechanisms. Agnon [51] and Moreland [52] consider the influence of the fan casing and duct resonances on the shape of the radiated spectra.

NOISE REDUCTION

Some general principles for noise reduction at the source are given below. The flow into an impeller or blade row should be as smooth as possible; low inlet turbulence (good system design) and casing boundary turbulence would reduce the broadband noise levels. Operating the fan at its design condition through speed variation rather than throttling would minimize impeller boundary layer or wake flow noise. A reduction of the noise at blade passing frequencies is achieved by a suitable selection of blade numbers, adequate axial spacing, and, if possible, non-radial stator vanes. Generally for a given pumping requirement, flow rate, and pressure head the broadband noise is reduced if the static efficiency and/or the pressure coefficient is increased (tip speed decreased). Alternately, for high flow applications -- cooling fans, boiler burner fans -- the pressure head (system pressure losses) should be kept to a minimum. A slightly different, but equally important, requirement is to eliminate any structural conditions that permit vibratory resonances.

Several novel noise reducing techniques have been examined in recent years. Dittmar ad Woodward [53] and Dittmar et al [54] showed that the broadband noise emitted by stator vanes interacting with inlet turbulent flow can be reduced by increasing the stator chord length. For a given inlet turbulence this increase in blade chord permits improved cancellation of the induced surface pressures, thus decreasing the net dipole strength.

A similar principle has been exploited by Filler [55], who suggests that inlet turbulence-generated blade noise can be reduced by cutting the blade trailing edge at an angle (swept edge) relative to the direction of the oncoming flow. The serrated blade edge, often quoted as the reason for quiet owl flight, has been investigated further by Longhouse [39], who used the principle to overcome vortex noise. In a more original technique the blades of an axial fan were manufactured from a porous but rigid material designed to cancel fluctuating pressures on either side of the blade. A noise reduction was observed but only at the expense of a small loss in fan efficiency. It was suggested that only the top 10 percent of blade span should be treated with porous material to overcome this loss in steady aerodynamic performance.

An interesting paper [57] indicates that excess noise might be generated if axial fans are incorrectly installed in duct work. The location of the fan relative to the duct ends could improve the acoustic coupling between the fan and the duct longitudinal resonant modes. In the worst possible case the blade passing tone could be amplified by the duct response.

CONCLUSIONS

A brief description has been given of the progress achieved in fan noise research. Not all of the important contributions have been included. The interested reader is referred to the excellent review papers by Morfey [1] and Cumpsty [2]. Some of the noise reduction methods described have been known for some time; in some instances the techniques have been applied with considerable success. Unfortunately this is not true in all sectors of the fan industry partly because of the increased cost of manufacture involved in the modifications and partly because not all of the reductions measured in the laboratory are realized in practical situations. It is expected that this situation will improve as environmental pollution in and around industry is better controlled. Noise reduction can even be an indirect result of improvements in industrial fan design. The recent introduction of variable pitch axial fan blades to improve the off design aerodynamic performance should also improve the noise characteristics.

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FINITE ELEMENT MODELING OF STRUCTURAL VIBRATIONS: A REVIEW OF RECENT ADVANCES

J.N. Reddy*

***Abstract** - This review of research in the finite element modeling of structural vibrations concentrates on literature published on the vibrations of the basic structural elements, namely, beams, plates, and shells since 1967.*

Any review of literature on the finite element modeling of structural vibrations must be incomplete because the subject has grown so quickly: hundreds of journals representing countries throughout the world now publish technical papers. This survey reviews finite element modeling of vibrations of basic elastic structural elements: beams, plates, and shells. All mechanical, aerospace, and civil engineering structures contain these basic elements in some combination. In addition, a number of references have to do with the finite element analysis of vibrations of specific structures composed of these elements. The literature on the subject of structural vibrations spans a ten-year period, and foreign references are incomplete.

THE FINITE ELEMENT METHOD

The finite element method is a numerical method for obtaining approximate solutions to a wide variety of problems described by differential or integral equations. It is a natural offspring of energy and matrix methods of structural analysis: the Rayleigh-Ritz and Galerkin philosophies are used to construct approximation functions, linear combinations of which represent the unknown solutions.

General description. The key to the success of the finite element method is the way in which approximation functions -- also called shape functions in the engineering literature -- are constructed. A given domain, or structure, is represented as a collection of a number of geometrically simple subdomains, called finite elements, which are connected at certain points called nodes. A typical element is isolated from the collection, and a variational problem is formulated -- using the Rayleigh-Ritz method, for example -- for arbitrary boundary conditions; the formulation requires only simple polynomials. A domain can in general be represented by more than one typical element. The variational problem is formulated in terms of the node values of the unknown functions and possibly their derivatives (as opposed to the arbitrary parameters used in the Rayleigh-Ritz method). The global, or system, model is obtained by fitting elements together. Continuity is obtained by using node values of the unknown functions, and possibly their derivatives at the boundaries between elements.

This representation of a structural system by a collection of discrete elements was borrowed from techniques used in the structural analysis of aircraft. For example, wings and fuselages are treated as assemblages of stringers, skins, and shear panels. The so-called framework method, in which a plane elastic solid is represented as a collection of bars and beams was introduced in 1941 [1]. The use of piecewise continuous functions defined over a subdomain to approximate the unknown function dates from the work of Courant [2]. He used an assemblage of triangular elements and the principle of minimum potential energy to study the St. Venant torsion problem. Although certain key features of the finite element method can be found in such early work, its formal introduction is attributed to the work of Argyris and Kelsey [3] and Turner, Clough, Martin, and Topp [4]. The phrase finite element was first used by Clough [5] in 1960. Since that time, the literature on finite element applications has grown to the point that many journals are now primarily devoted to the theory and application of the method. A review of the historical developments and the basic theory of the method is available in many textbooks oriented toward structural mechanics [6-13]. Mathematically-oriented texts are also available [14-18], as are nonstructurally-oriented ones [17, 18].

About 100 proceedings of conferences held on the finite element method are now available. Expository

**Associate Professor, School of Aerospace, Mechanical and Nuclear Engineering, University of Oklahoma, Norman, OK 73019*

papers on the finite element analysis of structures are also available [19-22], as are fairly complete lists of references on the method [6-17]. Several excellent bibliographies on the finite element method have been compiled [23-26].

Computer software. An important feature of the finite element method is that a systematic procedure is used to obtain properties of the element -- that is, its governing equations -- without regard to the specific problem. For example, if the equations corresponding to beam, plate, and shell elements are known, any structure containing these elements can be analyzed. Such flexibility coupled with the advent of the modern digital computer has resulted in the development of a number of general-purpose computer programs for analyzing a variety of complex engineering problems. Almost all of these programs have a certain common library of basic elements, but not everyone has the same degree of generality. A survey of structural mechanics computer programs is available [27]. Several survey papers on general-purpose finite element computer programs have also been published [28-32].

VIBRATIONS OF STRUCTURAL ELEMENTS

Beams

Beams are common components of many structural systems. Various levels of sophistication are to be found in beam analysis. The most simple analysis is based on the classical Bernoulli-Euler beam theory, which does not include the effects of shear deformation. Beam theories that account for transverse shear and rotary inertia are more important in vibration (especially in higher modes) analyses. Although both phenomena were first accounted for by Bresse in 1859, it is customary to refer to the beam theory that includes them as the *Timoshenko beam theory.* Shear deformation and rotary inertia must be included in predictions of frequencies when the wavelength is the same order as the length of the beam.

Vibration analyses based on the Bernoulli-Euler beam theory have been published [33-37]. The problem of maximizing the first natural frequency of a Bernoulli-Euler beam on a continuous elastic foundation has been treated by varying the cross-sectional area as a function of position and maintaining the volume (mass) of the beam as a constant [38].

In the finite element method, the mass matrices are computed either as a consistent (distributed) mass matrix or as a lumped mass matrix. In the case of a lumped mass matrix the total mass of the element is assumed to be distributed equally at the nodes. This assumption, although only approximate, results in a diagonal mass matrix, which in turn facilitates computation. The effect of lumped parameters on beam frequencies has been studied [39]. Higher-order beam elements -- elements in which higher degrees of polynomials than the cube are used -- have also been developed and used in the vibration analysis of beams; quintic polynomials, for example [40-42]. Tapered and twisted cantilever beams, which can be used to study the vibrations of turbine blades, have been considered [41, 43]. Shear walls are often treated as thin-walled beams of open cross section. Vibration analyses of shear walls are available [44-47]. Finite element analysis has also been applied to calculating the natural frequencies of simple curved sandwich beams during in-plane bending vibration [48, 49].

The effects of shear deformation and rotary inertia on vibrations of beams have been investigated [34, 43, 50-54], as has the effect of elasticity of the support -- as well as the effects of shear and deformation and rotary inertia -- on resonance frequency [55, 56]. A curved beam element has been developed that includes shear deformation and rotary inertia [57]; out-of-plane coupled bending and torsional vibration have been studied with this element. Results using thick and thin beam have been shown to be dependent on the axial thickness-to-radius ratio of the beam [58]. Timoshenko beam elements have also been applied to the vibration analysis of coupled electrical and mechanical systems [59-61]. Nonlinear vibrations of beams (not including shear deformation and rotary inertia) have been considered [62-67].

Plates and Shells

Conventional finite element methods of structural mechanics are based on extremum variational principles and thus involve total potential energy and total complementary energy. For boundary value problems of the order 2m, these extremum variational statements contain m-th order derivatives of the field variable. Therefore, the approximation (or shape) functions employed for the field variable must be such that: (i) the field variable and any of its partial derivatives up to the order (m−1) must

be continuous, and (ii) all uniform (or constant) states of the field variables and their partial derivatives up to order m should be represented by the approximation because, in the limit, the element size shrinks to a point. These conditions are called compatibility and completeness conditions respectively. *Any finite element that satisfies these conditions is called a conforming finite element.*

Completeness is automatically satisfied if the polynomials used in the shape function are complete to the m-th order. However, it is difficult to satisfy the compatibility condition. For the fourth and higher-order problems of plates and shells, these conditions require the use of higher order polynomials. In the case of plate bending ($m=2$), for example, the total potential energy expression contains second-order derivatives. Completeness is satisfied by complete quadratic polynomials; however, compatability requires higher order polynomials [68-74]. For instance, a compatible triangular element for classical theory of thin plates requires a quintic polynomial; the result is a 21 by 21 element stiffness matrix [75-77]. Thus, finite elements associated with higher order problems are algebraically complicated and hence computationally very expensive.

To remedy the difficulties of the conventional (compatible) finite element method, several nonconventional finite element methods have been proposed. In the so-called nonconforming finite element method [69, 78, 79] for boundary-value problems of the order 2m, the field variable is allowed to have finite discontinuities in the $(m-1)^{th}$ derivatives across the boundaries between elements. Convergence for such methods is not generally guaranteed. In hybrid finite element methods [80-82], continuity of $(m-1)^{th}$ order derivatives across boundaries between elements is treated as a constraint condition using Lagrange multipliers -- called the tractions in structural mechanics problems -- as additional dependent variables.

In mixed finite element methods [83, 84] additional dependent variables are introduced over the entire domain by decomposing the higher order problem into a set of lower order equations. These additional dependent variables are generally quantities of design interest. For example, in the plate bending problem the biharmonic equation is decomposed into a set of second order differential equations consisting of the moment equilibrium equation and the moment-deflection relationships; as a matter of fact, these equations are more basic than the biharmonic equation. The finite element method based on these equations thus requires only the *continuity of the dependent variables between elements*; therefore, linear approximations of the deflection and the bending moments are sufficient. Another advantage of the mixed methods is the increased accuracy of the additional or secondary field variables (i.e., stresses). The mixed method not only results in computationally simple elements but also in accurate prediction of stresses [85-89]. Hughes and Malkus [90, 91] recently discussed the equivalence of mixed finite elements and selective *and reduced integration-conventional finite elements.*

Plates. Plates offer economic as well as load-carrying advantages in the design of many types of structures. In some cases they can be used to replace structural elements of the shell, as in containers and ships, which are relatively expensive due to high fabrication costs. The finite element analysis of shell structures using plate elements assumes that the behavior of a shell can be adequately represented *by a surface built of small (triangular) plate elements* [92-97]. The error introduced by such approximation has been discussed [98].

Most papers on plate vibrations have employed conforming finite elements [99-127]. In one case [109] the finite element method was used to improve the analysis of rotating turbomachinery blades. Numerical results for natural frequencies and mode shapes were presented as functions of rotating speed and aspect ratio of the turbine blade. Variable thickness finite elements for plate vibrations have been derived [124, 125]. The results differed significantly from those obtained with elements of the same thickness only if higher vibration modes were considered. Rock and Hinton [128, 129] accounted for the effects of transverse shear in analyzing the free vibration of thick and thin plates; the results were compared with thin plate theory, Mindlin (thick) plate theory, and three-dimensional elasticity solutions. Convergence of eigenvalue solutions and bounds for eigenvalues for conforming elements have been investigated [130, 131]. Finite element analyses of flutter of panels are available [132-134].

Nonconforming elements have been applied to plate vibrations [101, 135, 136]. The hybrid finite element has been used in plate flutter and vibration [134, 137-140]. Flat-plate elements have been developed that are based on the hybrid stress finite element concept [141]. There are three quadrilateral elements involved; all have linear in-plane boundary displacements, assume linear in-plane stress, include the effects of shear deformation and rotary, as well as in-plane and transverse, inertia. One element was designed for single-layer, thin or moderately thick, plates and shells; the second element was for multilayer thin plates and shells; and the third was for thin or thick, single-layer or multilayer, plates and shells. Reddy and Tsay [141, 142] derived a simple, mixed rectangular plate element that gives better accuracies for natural frequencies when compared with certain conventional and nonconventional finite elements [101, 143].

As noted earlier in connection with beam vibrations, the lumped mass matrix is diagonal and the consistent mass matrix is complicated and computationally expensive. With lumped mass matrices, however, many elements may be needed to obtain sufficiently accurate results. On the other hand, lumped mass matrices usually tend to lower natural frequencies; a coarse mesh (i.e., stiffer structure) of compatible elements tends to raise them. Thus, for a fixed mesh size the lumped mass may give more accurate results than a consistent formulation [144]. Various mass lumping schemes and numerical integration rules have been examined for accuracy and computational cost [129, 145-147].

Nonlinear vibrations of thin elastic plates have been investigated by the finite element method [148-155]. Mei [149] studied the effect of geometric nonlinearity on the period of free vibration of plates and beams. The results were shown as period-amplitude plots and compared with those obtained by perturbation, Galerkin, and Duffing methods. The effects of in-plane shear deformation and rotary inertia on the flexural vibration of beams and thin plates have been studied [150]; the mixed plate element was developed to study the nonlinear bending and vibration of thin rectangular plates [88, 89, 141, 142]. Orthotropic plates have also been studied [148, 151, 153].

Shells. A number of papers on shell analysis have already been referred to in connection with plates; other vibration analyses by the finite element method are available [156-168]. Shells of revolution have been analyzed by ring (doubly curved) finite elements [158]. A four node, 28-degree-of-freedom element having all of its six body modes rigid was used to study the vibrations of a curved fan blade [159]. The first 12 natural frequencies were within ten percent error when a 4 by 4 mesh was used. A quasi-analytical finite element procedure based on the nonlinear version of Novozhilov's shell theory has been developed and used to obtain frequency and buckling eigenvalues of prestressed rotating anisotropic shells of revolution [163]. The usual centrifugal forces, as well as Coriolis forces, were included. Experimental and theoretical investigations of the dynamic behavior of a cylindrical shell with a cutout have been conducted [164]. Standard eigenvalue problems were solved for cylindrical shells with 40°, 80°, and 120° cutouts. Buckling and natural frequencies of standard plate and shell structures have been presented [165] using the "semi loof finite element" of Irons [169]. The accuracy of four finite element models of shells (based on four different shell theories) has been investigated [170]. In the computations, the continuous shells were replaced by finite-element models based on a triangular torus cubic finite element. This element differs from shell theory only in the axial variation of displacements. The vibrations of turbine blades have been modeled as thick, curved shells [171].

A number of hybrid finite elements have also been used to analyze the vibration of shells. Hybrid triangular flat plate elements with variable thickness [138, 139] were extended to treat a cylindrical shell [172, 173]. The relative accuracies of consistent and lumped masses in vibration analyses involving hybrid finite elements have been studied [174], as have nonlinear axisymmetric vibrations of thin shells of revolution [163, 175].

Symmetric structures do not always vibrate in a symmetric manner; structures containing more than one type of structural element can vibrate in nonrepeatable modes. The convenient aspects of symmetry and repeatability are thus lost in vibration problems, but certain simplifications are possible [176-179]. In general, the solution of a vibration problem requires more computational effort than does the solution of an equivalent static problem. However,

it is gratifying that reasonable accuracy of eigenvalues can be achieved with fewer degrees of freedom than are needed for a static solution. Irons [180, 181] suggested a procedure that utilizes the lumped mass concept to economize eigenvalue computation in vibration problems.

STRUCTURAL VIBRATIONS

Use of the finite element method to study the random vibrations of structures has been discussed [186]. Numerical methods for treating dynamics of large structural systems have been reviewed in a paper in which a detailed algorithm using a cubic interpolation of inertia forces and finite element approach was presented [187].

Papers have appeared on the vibration of turbomachinery blades and rotating discs. Dokainish and Rawtani [188] used the finite element method to determine the natural frequencies of rotating, pretwisted, cantilevered blades mounted on the periphery of a rotating disk at a staggered angle. The blade was treated as a shell with its middle surface divided into triangular elements; see also [189]. Axisymmetric flexural vibrations have been analyzed using ring finite elements [190]. The effect of axisymmetric in-plane forces due to axial rotations and shrink fits were included in the analysis. Mode shapes and natural frequencies of the curved blades of Darrieus-type windmill rotors have been presented [191]. Chamis [192] found that the numerical results obtained by the NASTRAN finite element program were in reasonable agreement with measured vibration frequencies and mode shapes of composite fan blades. Bhagat and Willmet [193] presented vibrational finite element analyses of planar mechanisms; see also [195].

Natural frequencies of box-type structures have been investigated by the finite element method [195-198]; vibration analyses of ship structures are available [199-203]. Finite element vibration analysis of earth and foundation structures such as dams has been discussed in various survey articles [204-207]. Vibration analyses of flight vehicle structures and liquid-propellant launch vehicles have appeared [208-209]. An extensive survey of the finite element analysis of reactor vessels has been given [210], as has a survey of the principles of the earthquake resistant design of nuclear reactor structures [211].

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BOOK REVIEWS

FUNDAMENTALS OF MARINE ACOUSTICS

J.W. Caruthers
Elsevier Scientific Publishing Company, NY (1977)

Volume 18 of the Elsevier Oceanography Series is a textbook for graduate students and upper-level undergraduates. It is based on material taught for several years in graduate courses and short courses at Texas A&M University and was originally published as a Texas A&M University Sea Grant Program report. In this form it was used for several university courses both in the United States and abroad.

The history may explain in part why its quality as a textbook is so high -- nothing beats hands-on experience in teaching a subject to students while the book is being assembled for use in teaching. All of the important features of an effective textbook can be found in this volume: a short and useful index, a bibliography of reference books, a selection of important references given as footnotes, problems at the end of seven of the ten chapters (with answers to selected problems in the back of the book), a coherent arrangement of the material into topics, and clear explanations throughout.

The topics treated cover all aspects of sound propagation in the ocean; environmental factors and civilian applications are emphasized. Coverage is nearly complete and includes: transducers (piezoelectric, ferroelectric, equivalent circuits, underwater explosions), hydrophones (calibration, directivity, cavitation), phased arrays, the sonar equations, propagation (refraction, channeling, shallow-water transmission, attenuation), reverberation (volume, surface, and bottom), noise, and signal processing. Chapter 6, the longest chapter, treats such important topics as the wave equation, Helmholtz's integral, the eikonal equation, ray theory, reflections, interference, and normal modes.

With this much material, the textbook-writer has two options. He can provide introductions that emphasize the complexity of the topic, limitations of the theories, exceptions, and unknown areas in order to prepare his students for actual situations should they wish to follow up a topic in detail. Mr. Caruthers has taken the other course, which is to strip away distracting details and to present each topic as a simple, complete, and understandable whole. This gives the student confidence that he can master the topic as presented but leaves it up to him to discover limitations, exceptions, and extensions later. He can do so from a firm basis in the fundamentals of each topic; the first option tends to produce only confused students.

Experts in the various fields covered by this book can easily point out omissions of detail; e.g., formulas cannot be applied as easily as indicated, exceptions have been ignored. However, it is instructive to see how the author has selected a segment of each topic, explained it, and provided examples.

One drawback is the text's apparent age: a penalty of assembling material for a book over several years of teaching a course. Most of the references, for example, date from 1957 to 1967. The book also uses a hodgepodge of units -- miles, centimeters, pounds, dynes -- reflecting the different conventions originally adopted by the fields covered. The variations may be troublesome to students, who are also required to learn things in units which, it is hoped, will disappear in the next few years as the Systeme Internationale becomes fully operational in the United States. A few SI units are indicated by footnotes.

The book is highly recommended as a textbook for teaching a comprehensive introductory course. The chapter headings and index make it useful as a quick reference to the basics of the topics covered. The discussions, examples, and problems also make

it suitable for self study.

R.L. Bort
Code 8406
Ocean Technology Division
Naval Research Laboratory
Washington, D.C. 20375

FOUNDATIONS OF AERODYNAMICS: BASES OF AERODYNAMIC DESIGN

A.M. Kuethe and C.-Y. Chow
John Wiley & Sons, Inc., NY (1976)

This is the third edition of the classic, Foundation of Aerodynamics, by Kuethe and Schetzer, the first two editions of which were published in 1950 and 1959 respectively. The third edition is essentially unchanged: it is a basic fluid mechanics book meant for an undergraduate first course in fluid mechanics. It can also serve as a reference for the engineer in need of information about the fundamentals of fluid mechanics and fluid forces. The extensive bibliography will be useful in investigations requiring details about areas that are given cursory exposure in the book.

The main differences between this and the previous edition are that the panel method is used to evaluate flow fields about generally-shaped bodies, interactions between different-shaped bodies and the boundary layer control theory are described, the use of numerical techniques in solving analytical problems has been expanded, the metric system is used throughout, and more problems have been added at the end of every section (215 total as opposed to 168).

The book is divided into two parts: inviscid theory (Chapters 1-13) and viscous theory (Chapters 14-19). Interactions between inviscid and viscous fluids are not considered. The inviscid part of the book contains six chapters on incompressible fluid and seven on compressibility. The basic concepts of fluid properties are introduced and the basic equations derived -- first for the airfoil and then for a finite wing. Both the airfoil and wing are analyzed in incompressible inviscid fluid; the pressure distribution about each body is obtained. The effects of compressibility are introduced, and both normal and oblique shock waves are explained. Inviscid theory is completed with a linearized analysis of slender bodies.

Chapters 14-16 consider laminar viscous fluids, and Chapters 17-19 deal with turbulent phenomena. Concepts pertaining to viscosity in general and boundary layers in particular are introduced, and both incompressible and compressible laminar boundary layers are analyzed. The meaning of transition, including the factors that affect it and the turbulent field it causes, are described. The book ends with a chapter on the various ways that different boundary layer controls methods can be used.

Chapter 1 covers the basics of fluid properties and fluid statics. Chapter 2 describes the kinematics of flow fields. Chapter 3 contains a derivation of the basic equations of inviscid flow fields. Chapter 4 deals with flow due to sources, dipoles, vortices, and flow field about cylinders; it contains a numerical analysis of flow field about generally-shaped bodies as developed by A.M.O. Smith. Chapter 5 covers the aerodynamic characteristics of symmetrical and cambered airfoils and generalizes this into a numerical analysis for more complex shapes. Chapter 6 considers finite wings, with and without twists, and describes wing stability and the interference effects of wings, ground, and/or wind tunnel walls. Chapter 7 introduces the effects of compressibility in both the continuity and the momentum equation. Chapter 8 contains a derivation of the energy equation for compressible fluids. Chapter 9 contains solutions for the flow fields about the Laval nozzle, as well as solutions for one-dimensional flows with and without friction and with and without the addition of heat. Chapter 10 introduces and discusses normal and oblique shock waves. In Chapter 11, the compressible fluid equations are linearized for small perturbations. In Chapter 12 these equations are used to analyze airfoils in subsonic, transonic, and supersonic flows. Chapter 13 contains solutions for the effect of sweepback and wing-fuselage combinations in compressible flow fields.

Chapter 14 contains derivations of the boundary layer equations and discusses the concept of similarity of flow fields. Chapter 15 contains solutions for incompressible viscous flow fields in tubes and on flat plates and an introduction to the Von-Karman

integral relationship and its solution by the Pohlhausen analysis. Chapter 16 is an introduction to laminar boundary layers in compressible fluids and contains some simplified solutions. Chapter 17 is an excellent introduction to transition phenomena that occur as the boundary layer goes from laminar to turbulent. The physical phenomenon is described, as well as the factors that affect the transition -- pressure gradient, suction, heat, compressibility, noise, roughness, and surface curvature. Different experimental techniques for detecting transition are also discussed. Chapter 18 covers turbulent shear flows. It includes a general description of turbulence and solutions to the simple flow field; i.e., fully developed flows in tubes and channels and boundary layers over flat plates. Chapter 19, the only completely new chapter in the book, deals with boundary layer control over airfoils by suction and/or blowing. Multi-component airfoils are analyzed, and some results are presented.

Although the book is recognized as excellent for the areas included, it is regrettable that the authors chose to restrict the scope of the book to aerodynamics. Many different scientific fields now utilize the equations of motion and the techniques originally developed for the aerodynamicist. Discussions on the application of these techniques to such fields as hydrodynamics, acoustics, blood flow, aquatic animal propulsion, tides, atmospheric boundary layers, solar wind flows, wind turbines, and mathematical models for weather prediction would have been a welcome addition. The inclusion of some of these topics, even to the exclusion of certain information in the book, would have immensely expanded its usefulness.

Dr. Mauro Pierucci
Principal Engineer - Dept. 443
GENERAL DYNAMICS/Electric Boat Div.
Groton, CT 06339

VISCOELASTICITY

W. Flügge
Springer-Verlag (1975)

The book is an introductory text on the linear theory of viscoelasticty. The stated objective of the book is to present "the theory of viscoelasticity as an instrument of logical analysis. Basic assumptions are plausibly explained, and mathematical reasoning is used to derive results from them, which are deemed of interest for engineering tasks."

Indeed the book is meant for those who are interested in applications and need an introduction to the subject of mechanical behavior of simple structures with viscoelastic properties under various types of loading. In this respect it serves as a very useful and readable introduction to the subject of viscoelasticity. The author has taken great pains to explain and illustrate (by examples) the difference in mechanical behaviors of structures obeying different viscoelastic constitutive laws.

The book is divided into eight chapters. Chapter 1 is a discussion of various viscoelastic models obtained by a combination of springs and dashpots. Chapter 2 is on hereditary integrals. Chapters 3 and 4 deal with viscoelastic beams. Vibrations and wave propagation are discussed in Chapters 5 and 6, and buckling in Chapter 7. Chapter 8 contains a brief treatment of three-dimensional problems.

S.K. Datta
Professor of Mechanical Engineering
University of Colorado
Boulder, CO 80309

SHORT COURSES

1979

JANUARY

NONDESTRUCTIVE EXAMINATION

Dates: Repeated continuously thoughout the year (1 day to 3 weeks)

Place: Los Angeles, CA

Objective: For those requiring qualification and certification, theory and practical application courses are available for either one or all of the basic techniques; Ultrasonics, Radiographic, Magnetic Particle, Liquid Penetrant, Eddy Current and Helium Leak. Also Special Radiation Safety and Radiographic Film Interpretation courses for Level II and Level III training are presented. The selection of courses is also applicable to those who require engineering understanding, supervision training or state-of-the-art development.

Contact: C.A. Parker, Nuclear Training Center, Atomics International, P.O. Box 309, Canoga Park, CA 91304 - (213) 341-1000, Ext. 2811.

VIBRATION TESTING AND DYNAMIC ANALYSIS OF MACHINES AND STRUCTURES

Dates: 13 seminars throughout the year

Place: San Diego, CA

Objective: Individual seminars will cover such wide-ranging subjects as machinery vibration, structural deformation and response, analysis of the modal behavior of mechanical assemblies subjected to outside forces, and the application of vibration analysis to on-line quality control in the manufacturing process. Cost effectiveness will be stressed throughout the entire series, including down-to-earth discussions of how vibration analysis can save money through preventing machinery failure, eliminating costly testing of engineering prototypes and improving product reliability through scientific design and testing.

Contact: Robert Kiefer, Training Manager, Spectral Dynamics, P.O. Box 671, San Diego, CA 92112 - Tel. (714) 268-7100.

TRANSMISSION LINE INSTRUMENTATION, DATA ANALYSIS AND DESIGN

Dates: Contact TIT for details

Place: Ibid

Objective: Severe 1978-79 winter winds will further endanger vital USA high-tension electrical power grids. Wind-caused vibration of transmission lines is the central concern of this new course. Wind-induced vibration failure modes include: Fastenings within insulator stacks fatigue, dropping conductors, Tower structures fatigue and/or loosen, Conductors crack; if cracks (often accompanied by fretting corrosion) penetrate sufficiently, conductors would break and drop, and Dampers commonly fail and drop off the lines. Utilities are using accelerometers and other instruments to study conductor motions. Measurements demonstrate which dampers are most effective.

Contact: Wayne Tustin, 22 E. Los Olivos St., Santa Barbara, CA 93105 - (805) 963-1124.

STRUCTURED PROGRAMMING AND SOFTWARE ENGINEERING

Dates: January 8-12, 1979

Place: The George Washington University

Objective: This course provides up-to-date technical knowledge of logical expression, analysis, and invention for performing and managing software architecture, design, and production. Presentations will cover principes and applications in structures programming and software engineering, including stepwise refinement, program correctness, and top-down system development.

Contact: Continuing Engineering Education Program, George Washington University, Washington, D.C. 20052 - (202) 676-6106 or toll free (800) 424-9773.

ENVIRONMENTAL ACOUSTICS

Dates: January 10 to March 21, 1979 (Wednesdays, 7-10 p.m.)

Place: UCLA Extension, Los Angeles, CA

Objective: This course will cover acoustic measurements, noise metrics and human criteria, sound propagation and attenuation, vehicle and aircraft noise, sound in rooms, acoustic properties of materials, transmission loss, ducts and mufflers, sound transmission in buildings, vibration control and impact isolation, sound reinforcement, noise law and environmental impact.

Contact: Barbara Marcus, UCLA Extension, P.O. Box 24902, Los Angeles, CA 90024 - (213) 825-1901.

SHOCK AND VIBRATION ENGINEERING FOR AEROSPACE SYSTEMS

Dates: January 9 to March 20, 1979 (Tuesdays, 7-10 p.m.)

Place: UCLA Extension, Los Angeles, CA

Objective: This course will cover each facet of shock and vibration engineering in aerospace systems.

Contact: Barbara Marcus, UCLA Extension, P.O. Box 24902, Los Angeles, CA 90024 - (213) 825-1901.

FEBRUARY

VIBRATION AND LOOSE PARTS MONITORING SYSTEMS AND TECHNOLOGY

Dates: February 5-8, 1979

Place: Los Angeles, California

Objective: A course designed for users, utility designers specifying systems, installers, operators, and analysts of Vibration and Loose Parts Monitoring Systems. Classroom instruction in theory, intallation, calibration, alarms and location, signature analysis, noise analysis, and troubleshooting and servicing. Practical demonstration includes student "hands-on" operation of equipment.

Contact: C.A. Parker, Nuclear Training Center, Atomics International, P.O. Box 309, Canoga Park, CA 91304 - (213) 341-1000, Ext. 2811.

VIBRATION AND SHOCK SURVIVABILITY

Dates: February 5-9, 1979

Place: Tustin Institute of Tech., Santa Barbara

Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis, also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, *rather than upon mathematics and* theory.

Contact: Wayne Tustin, 22 E. Olivos St., Santa Barbara, CA 93105 - (805) 963-1124.

FLOW-INDUCED VIBRATION PROBLEMS AND THEIR SOLUTIONS IN PRACTICAL APPLICATIONS: TURBOMACHINERY, HEAT EXCHANGERS AND NUCLEAR REACTORS

Dates: February 12-16, 1979

Place: The University of Tennessee Space Inst.

Objective: The aim of the course is to provide practicing engineers engaged in design, research and service, an in-depth background and exposure to various problems and solution techniques developed in recent years. Topics to be covered will be the fundamental principles of unsteady fluid flow, structural vibration and their interplay; review of the morphology of flow-induced vibration; state-of-the-art discussion upon theory, experimental techniques and their interaction; methodology of *alleviation*.

Contact: Jules Bernard, The University of Tennessee Space Institute, Tullahoma, TN 37388 - (615) 455-0631 - Ext. 276 or 277.

MACHINERY VIBRATIONS COURSE

Dates: February 26 - March 1, 1979

Place: Shamrock Hilton Hotel, Houston, Texas

Objective: This course on machinery vibrations will cover physical/mathematical descriptions, calculations, modeling, measuring, and analysis. Machinery vibrations control techniques, balancing, isolation, and damping, will be discussed. Techniques for machine fault diagnosis and correction will be reviewed along with examples and case histories. Torsional vibration measurement and calculation will be covered.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, Suite 206, 101 W. 55th St., Clarendon Hills, IL 60514 - (312) 654-2254/654-2053.

MARCH

MACHINERY VIBRATION SEMINAR

Dates: March 6-8, 1979

Place: New Orleans, Louisiana

Objective: To cover the basic aspects of rotor-bearing system dynamics. The course will provide a fundamental understanding of rotating machinery vibrations; an awareness of available tools and techniques for the analysis and diagnosis of rotor vibration problems; and an appreciation of how these techniques are applied to correct vibration problems. Technical personnel who will benefit most from this course are those concerned with the rotor dynamics evaluation of motors, pumps, turbines, compressors, gearing, shafting, couplings, and similar mechanical equipment. The attendee should possess an engineering degree with some understanding of mechanics of materials and vibration theory. Appropriate job functions include machinery designers; and plant, manufacturing, or service engineers.

Contact: Mr. Frank Ralbovsky, MTI, 968 Albany-Shaker Rd., Latham, NY 12110 - (518) 785-2349.

MEASUREMENT SYSTEMS ENGINEERING

Dates: March 12-16, 1979

Place: Phoenix, Arizona

MEASUREMENT SYSTEMS DYNAMICS

Dates: March 19-23, 1979

Place: Phoenix, Arizona

Objective: Program emphasis is on how to increase productivity, cost-effectiveness and data-validity of data acquisition groups in the field and in the laboratory. The program is intended for engineers, scientists, and managers in industrial, governmental, and educational organizations. Electrical measurements of mechanical and thermal quantities are the major topics.

Contact: Peter K. Stein, 5602 E. Monte Rosa, Phoenix, AZ 85018 - (602) 945-4603/946-7333.

APPLICATIONS OF THE FINITE ELEMENT METHOD TO PROBLEMS IN ENGINEERING

Dates: March 12-16, 1979

Place: The University of Tennessee Space Inst.

Objective: This course will concentrate on material developed recently and provide a solid foundation for those relatively new to the field. Topics to be covered are the treatment of mixed type equations which occur in transonic flow and wave motion in nonlinear solids, mixed type elements which are of importance in systems such as the Navier-Stokes equations, the interrelationship between the equation formation and the iterative scheme needed to solve any of the nonlinear equations, the advantages of hybrid elements, and the use of interactive graphics as an aid to problem solution.

Contact: Jules Bernard, The University of Tennessee Space Institute, Tullahoma, TN 37388 - (615) 455-0631, Ext. 276 or 277.

APRIL

MACHINERY VIBRATION MONITORING AND ANALYSIS SEMINAR

Dates: April 10-12, 1979

Place: New Orleans, Louisiana

Objective: This seminar will be devoted to the understanding and application of vibration technology to machinery vibration monitoring and analysis. Basic and advanced techniques with illustrative case histories and demonstrations will be discussed by industrial experts and consultants. Topics to be covered in the seminar include preventive maintenance, measurements, analysis, data recording and reduction, computer monitoring, acoustic techniques, misalignment effects, balancing, mechanical impedance and mobility, turbomachinery blading, bearing fault diagnosis, torsional vibration problems and corrections, and trend analysis. An instrumentation show will be held in conjunction with this seminar.

Contact: Dr. R.L. Eshleman, Vibration Institute, Suite 206, 101 W. 55th St., Clarendon Hills, IL 60514 - (312) 654-2254.

CORRELATION AND COHERENCE ANALYSIS FOR ACOUSTICS AND VIBRATION PROBLEMS

Dates: April 16-20, 1979

Place: UCLA

Objective: This course covers the latest practical techniques of correlation and coherence analysis (ordinary, multiple, partial) for solving acoustics and vibration problems in physical systems. Procedures currently being applied to data collected from single, multiple and distributed input/output systems are explained to: classify data and systems; measure propagation times; identify source contributions; evaluate and monitor system properties, predict output responses and noise conditions; determine nonlinear and nonstationary effects; and conduct dynamics test programs.

Contact: P.O. Box 24902, Continuing Education in Engineering and Mathematics, UCLA Extension, Los Angeles, CA 90024 - (213) 825-3344/825-1295.

MAY

STRUCTURED PROGRAMMING AND SOFTWARE ENGINEERING

Dates: May 21-25, 1979

Place: The George Washington University

Objective: This course provides up-to-date technical knowledge of logical expression, analysis, and invention for performing and managing software architecture, design, and production. Presentations will cover principles and applications in structures programming and software engineering, including stepwise refinement, program correctness, and top-down system development.

Contact: Continuing Engineering Education Program, George Washington University, Washington, D.C. 20052 - (202) 676-6106 or toll free (800) 424-9773.

JUNE

ACOUSTIC EMISSION STRUCTURAL MONITORING TECHNOLOGY

Dates: June 18-19, 1979

Place: Los Angeles, California

Objective: A theory and practice course covering each of the various facets of acoustic emission structural monitoring technology; basic phenomena, state-of-the-art applications, field testing experience, applicable codes and standards and instrumentation design and calibration. Includes "hands-on" operation of minicomputer and microcomputer acoustic emission systems. This course is designed for potential users of acoustic emission structural monitoring systems.

Contact: C.A. Parker, Nuclear Training Center, Atomics International, P.O. Box 309, Canoga Park, CA 91304 - (213) 341-1000, Ext. 2811.

NEWS BRIEFS

news on current and Future Shock and Vibration activities and events

NOISEXPO '79
National Noise and Vibration Control Conference and Exhibition

April 2-5, 1979

NOISEXPO '79 will be presented April 2-5, 1979, at the Hyatt Regency O'Hare, five minutes from the Chicago O'Hare Airport. The conference program features a unique series of mini-courses on noise and vibration related topics. The program also includes a luncheon session, showings of canned presentations in a mini-theater, and technical sessions featuring papers on: hearing conservation, instrumentation, product noise and vibration, industrial noise and vibration, structural dynamics, and environmental noise. NOISEXPO '79 serves individuals who are concerned with noise and vibration control, hearing conservation and environmental noise regulation. Engineers, technicians and managers from industry; personnel from governmental agencies; educators; and researchers will benefit from the program. Advance registration is available from: NOISEXPO, 27101 E. Oviatt Road, Bay Village, OH 44140. Phone: (216) 835-0101.

NOISE-CON '79
National Conference on Noise Control Engineering Machinery Noise Control

April 30-May 2, 1979

NOISE-CON 79, the 1979 National Conference on Noise Control Engineering, will be held at Purdue University in West Lafayette, Indiana, on April 30 - May 2, 1979.

The theme of NOISE-CON 79 is Machinery Noise Control. Several different sessions will be held in which both invited and contributed papers will be presented. Ten sessions are presently planned on the following topics: agricultural and construction equipment noise, forging and impact noise, metal cutting noise, noise of engines and components, diagnostic measurements, measurement of noise emission, noise of machine elements, hydraulic and pneumatic system noise, mining equipment noise and noise of home appliances. For information on the conference, contact: NOISE-CON '79, 116 Stewart Center, Purdue University, West Lafayette, IN 47907.

ACOUSTIC EMISSION DEVICE WILL WARN OF GROWING FLAWS IN STEEL BRIDGES

A battery-powered instrument the size of a portable radio may soon be used to detect the growth of material flaws in steel bridges. It was developed for the Federal Highway Administration in sponsored research at Batelle's Pacific Northwest Laboratories, Richland, Washington. The instrument system is an advancement of acoustic emission technology developed earlier at Battelle. With acoustic emission, highly responsive sensors monitor elastic waves produced by energy released during deformation or cracking of material.

The system includes three sensors that are magnetically mounted on the bridge. Signals picked up by the sensors are fed back into the primary unit and stored on digital memory chips. The tiny chips, about 1" long and ¾" wide, permit unattended operation and data collection for up to several months. The unit can be powered by batteries or by a 110 volt current. It is portable and weighs less than seven pounds. Project leader Phillip H. Hutton of Battelle's Engineering Physics Department said that adjustments to the master unit permit monitoring a variety of area sizes and configurations. This may range from a few square inches at the tip of a known crack to a weld 30-40 feet long.

Hutton noted that: "This unit can be used for short-term sample monitoring of critical bridge details. However, its primary use will probably be in long-term monitoring of bridges, since material flaws often grow slowly." The unit was successfully field tested for five weeks, including operation at temperatures of near zero.

CALL FOR PAPERS

THE SECOND INTERNATIONAL SYMPOSIUM ON INNOVATIVE NUMERICAL ANALYSIS IN APPLIED ENGINEERING SCIENCE

June 16-20, 1980

The Second International Symposium on Innovative Numerical Analysis in Applied Engineering Science will be held June 16-20, 1980 at the Ecole Polytechnique de Montreal in Montreal, Canada. Papers are solicited in all areas of engineering science such as solid and fluid mechanics, electrical engineering, acoustics, etc. with emphasis on "non-standard" numerical analysis. Papers on innovative numerical analysis which emphasize technology transfer topics, hybridization of analysis methods and 'new' technology are strongly encouraged.

Extended abstracts of approximately 1000 words, in French or English, are required by March 15, 1979. Final accepted papers of up to 10 pages will be required by December 15, 1979 for publication in the symposium proceedings. Five copies of each abstract should be sent to:

Dr. A. Chaudouet (Europe)
CETIM
Boite Postale No. 67
60304 Senlis, Cedex, France

or to

Dr. T. Cruse
Pratt and Whitney Aircraft
East Hartford, CT 01608

TIRE NOISE CONFERENCE

August 28-30, 1979

The conference will be held August 28-30, 1979 at the Sheraton Hotel in Stockholm, Sweden. The objective of the symposium is to provide a base for reducing tire noise, unify measurement methods and find a closer approach of the mechanisms of tire noise generation. Areas covered include: Regulations standard and financial aspects of tire noise control, Measurement technique, Defining road and tire properties, Generating mechanisms and parameter influence, and Practical tire noise reduction.

Further information can be obtained from National Swedish Board for Technical Development (STU), Attn: Ms Inger Dunér, Private Bag, S-100 72 Stockholm, Sweden, Phone + 46 8 744 51 00.

50TH SHOCK AND VIBRATION SYMPOSIUM MEETING ANNOUNCEMENT

The 50th Shock and Vibration Symposium will be held on October 16-18, 1979, at the Antlers Plaza Hotel, Colorado Springs, Colorado. The U.S. Air Force will be the host. For information, contact Henry C. Pusey, Director, The Shock and Vibration Center, Code 8404, Naval Research Laboratory, Washington, D.C. 20375 - Tele. (202) 767-3306.

REVIEWS OF MEETINGS

49TH SHOCK AND VIBRATION SYMPOSIUM

17-19 October 1978
International Inn
Washington, D.C.

The 49th Shock and Vibration Symposium, sponsored by the Shock and Vibration Information Center (SVIC), was held in Washington, D.C. in October. It was hosted by the NASA, Goddard Space Flight Center, Greenbelt, Maryland. The formal technical program consisted of more than 60 papers (see Vol. 10, No. 9 of the DIGEST for the complete program; paper summaries are available from SVIC). There was a session of more than 15 short discussions. Henry Pusey, Director of the SVIC, the members of the SVIC staff, and the Program Committee are to be congratulated for assembling an interesting program. W. Brian Keegan of the Goddard Space Flight Center was responsible for organizing an excellent opening session and outstanding local arrangements. Among the 300 participants were representatives of the federal government, industry, and academic institutions. The attendees participated in both the formal and informal technical programs, thereby effecting a meaningful transfer of shock and vibration technology.

The Opening Session

The opening session was chaired by W. Brian Keegan. Symposium participants were welcomed on behalf of the NASA, Goddard Space Flight Center by Dr. Robert S. Cooper, Director of the Center. Dr. Cooper stressed the importance of the Symposium to Goddard and NASA in its role of helping to solve shock and vibration problems in space systems. Andrew J. Stofan, Deputy Associate Administrator for Space Sciences, NASA, presented the keynote address. Mr. Stofan noted the fact that he never received good news from shock and vibration engineers in his fifteen years of experience with launch vehicles. Shock and vibration problems were always present but were solved. He reviewed some past problems and NASA's future program plans. Mr. Stofan described some of the pogo problems encountered in the early Titan-Centour vehicles. In the process of solving these problems he observed the fact that analytical tools lag hardware in development and shock and vibration people are typically brought in too late. Analytical tools have to be improved for large structures in space. Among the programs described by Mr. Stofan were:

- GALILEO SPACECRAFT - fly by Mars and Juniper in 1985 (dynamics and control problems)
- SPACE TELESCOPE - 1983 (problems in absolute pointing accuracy)
- LARGE AREA MODULAR ARRAY - look for x-ray sources
- UV OPTICAL INTERFEROMETER - measure sources near edge of solar system
- GEOSTATIONARY PLATFORM - remote area communications
- X-RAY PINHOLE TELESCOPE - determine x-ray sources in Sun
- GRAVITY WAVE INTERFEROMETER

Mr. Stofan observed that the technology does not exist for some of the projects and that analysts will have to work closely with designers.

The first invited paper was "The Role of Dynamics in DoD Science and Technology Programs" by Dr. George P. Millburn of the Office of the Deputy Director of Research and Engineering. Dr. Millburn noted that the SVIC services form a central role in DoD RT&DE programs. He observed that we must use the latest technology to combat the lack of people and numbers of hardware in our defense. He reviewed the DoD research and development and noted the difficult problem of distributing the R&D effort to government laboratories, contract research firms, and Universities. The key thrusts in DoD research include artificial intelligence, smart weapons, directed beams, microelectronics, and composite materials. Dr. Millburn observed the need for tech-

nology transfer groups such as SVIC in an effort to eliminate costly duplication.

Dr. Michael Card of NASA, Langley Research Center presented the second invited paper on "Dynamics Problems in Large Space Structures." Dr. Card showed previous large vehicles (EXPLORER ('49), ECHO II ('64), SKYLAB ('73)) launched by NASA. All had reliability problems. New large space structures have a lot of open truss work. Dr. Card described the three main areas with dynamics problems -- structural analysis, dynamic loads, and controls. Problems have begun to arise with saturated computer programs and with scaling. Dr. Card reviewed the common dynamic modeling and computation techniques and discussed his progress in continuum analyses for repetitive structures. He also reviewed load sources for large space structures including ground handling, boosting, deployment, assembly, control, thrusting, docking, operations, and environments. Low frequencies (to .1 Hz) of large space structures are a problem -- for instance low earth orbit forcing frequency is .002 Hz. Dr. Card talked about means for control of large space structures including counter rotating rings and adaptive control. He summarized with a discussion on methods for structural analysis, dynamic loads, and controls.

Dr. John F. Wilby of Bolt Beranek and Newman gave the third invited paper, "Analytical Model for Predictions of Noise Levels in Space Shuttle Payload Bay." Their work on acoustic noise environment includes efforts on mathematical analysis and experimental validation. The problems involve structural response and acoustic radiation. He showed program development, analytical models, and scale test models. Statistical energy analysis was used for high frequency vibration and modal analysis for low frequency. The analysis was conducted in one-third octave bandwidths. Testing of the OV 101 model will be conducted at the Palmdale, California test facility followed by a second test at Edwards Air Force Base using F104 aircraft as the noise source. Dr. Wilby showed the microphone and accelerometer test locations. The payload modeling was particularly interesting for this test program. Current and future work on this program was discussed by Dr. Wilby.

The Technical Program

The technical program contained the following formal sessions: Vibration and Acoustics, Blast and Shock, Modal and Impedance Analysis, Human Response to Vibration and Shock, Isolation and Damping, Dynamic Analysis, Structure Medium Interaction, and Case Studies in Dynamics.

In the session on vibration and acoustics, papers were presented on fatigue, signature analysis, shaker waveform control, coherence functions and cavity noise phenomena and its measurement. The topic of blast and shock was encountered in a session involving pyrotechnic shock simulation, snaps in structures, blast from bursting, frangible pressure spheres, wave propagation in structures, and shock buffering for hydrodynamic rams. In the area of modal and impedance analysis, papers on low frequency environments, flight vehicle vibration mode modification, excitation of principal modes, determination of dominant modes in a structure, and combination of modal responses and shock spectra were presented. A special session on human response to vibration and shock was arranged for the Symposium by Dr. John C. Giugnard of the Naval Aerospace Medical Research Laboratory Detachment.

The opening paper on problems and progress in biodynamics was given by Dr. H.E. Von Gierke of Wright-Patterson AFB. Other papers contained in this excellent session concerned musculoskeletal response to impact loading, human response to impact, whole-body vibration of heavy equipment operators, vibration characteristics of the hand, vehicle ride quality, and criteria. A session on isolation and damping contained papers on computer aided design on passive vibration isolators for electro-optical systems, plate transmissibility, liquid spring modeling and system identification, slip damping in turbine blades, elastomer damping, and measurement of material damping behavior.

In the area of dynamic analysis, a session was conducted which contained papers on fluid transients, nonlinear system response, random time domain analysis, shock spectra, explosively propelled plates, and dynamically loaded linear viscoelastic structures. Structure medium interaction topics were discussed in a special session which contained papers on fluid-structure interaction calculations considering long wave length effects, simplified shock design of underground structures, blast loading of underground concrete structures, loads on buried structures, and

optimization of reinforced concrete slabs. An interesting session involving case studies in dynamics involved papers on system fatigue in hydrofoil operation, rotor-bearing system dynamic response to unbalance, dynamic characteristics of a turbine generator on its low tuned foundation, and ride quality in tractor trailers.

Papers presented at the Symposium will be reviewed for quality of technical content and presentation and published in the 49th Shock and Vibration Bulletin, which will be available from the SVIC.

R.L.E.

STANDARDS REVIEW

AMERICAN NATIONAL STANDARDS INSTITUTE COMMITTEE S2 - Mechanical Vibration and Shock

The semiannual meeting of ANSI S2 was held at the 49th Shock and Vibration Symposium on October 19, 1978 in Washington. The activities of the various working groups are reviewed below.

S2-51/S2-68
Calibration Methods for Shock and Vibration Pickups

Since both committees were inactive a new working group, S2-81, "Use and Calibration of Vibration and Shock Measuring Instruments" was formed under the chairmanship of M.R. Serbyn of the National Bureau of Standards. Mr. Serbyn is in the process of consolidation of tasks of S2-51/S2-68 and will be enlisting new members and developing a new scope of activities. S2-81 will be involved with SC3 of ISO/TC108 specifically on the revision of documents on the calibration and specifying of shock and vibration pick-ups for shock and vibration measurements.

S2-54
Atmospheric Blast Effects

The fourth draft of a document on source airblast description for single point explosions in air with a guide to evaluation of atmospheric propagation and effects has been submitted for S2 ballot. Negative ballots are presently being reviewed and the document is being processed to satisfy negative comments. The purpose of this manual is to provide concensus quantitative definitions of explosion characteristics, effects of atmospheric propagation, and typical responses to explosion waves.

S2-63
Vibration and Shock Isolators

This committee is currently working on a revision of ANSI S2.8-1972 "Guide for Describing the Characteristics of Resilient Mountings." This revision is being circulated among ANSI committee members and SAE committee G-5 members for review.

S2-65
Balancing Technology

This committee has several documents in preparation for flexible rotor balancing. In addition a document on rigid rotor balancing is under revision. Comments on S2119-1975, "Balance Quality of Rotating Rigid Bodies" should be forwarded to S. Feldman of NKF Engineering Associates. This committee under the chairmanship of Dr. Neville Rieger has been broken into the following subcommittees:

Subcommittee	Chairman
Rigid Rotors	Feldman
Flexible Rotors	Rieger
Terminology	Stadelbauer
General Items	Maedel
Balancing Machines and Enclosures	Stadelbauer

S2-67
Measurement and Evaluation of Vibration and Shock in Land Vehicles

Dr. Karl Hedrick, the new chairman is in the process of obtaining new members and a scope of activity.

S2-72
Vibration Testing

This working group is engaged in the activities of the ISO/TC108 counterpart Wg5. ISO/DP6070 - an international standard for auxiliary tables for vibration generators is at the first draft stage. ISO/DIS-5344, "Electrodynamic Test Equipment for Generating Vibration - Methods for Describing Equipment Characteristics" is in its final stages of development.

S2-73
Characterization of Damping Materials

A meeting of S2-73, Damping Properties and Techniques, was held at the 49th Shock and Vibration

Symposium. A new document on measurement and analysis of damping properties was presented at this meeting. This document is based on work performed at Wright Patterson AFB on damping characterization techniques under the direction of Dr. John Henderson, who is also chairman of this committee. Dr. D.I.G. Jones of Wright Patterson AFB will be the co-chairman of this committee. An effort is presently being made to include more members and to coordinate efforts with ASTM Committee E33 on environmental acoustics.

S2-74
Measurement of Mechanical Mobility

This active Committee under the guidance of Dr. Baade is working on a set of five standards covering the various aspects of mobility. The first of the five documents - on terminology and transducers - has been concluded. Negative votes resulting from a recent S2 ballot have been resolved and the new document is being prepared for publication.

S2-76
Vibration Levels of Machines

Several machinery vibration standards are being developed in this working group under the direction of Paul Maedel. A draft standard on shaft vibration measurement has just been completed for submission to the ISO/TC108/SC2/Wg7 working group meeting in Berlin. Negative votes are being resolved on a proposed ANSI Standard for evaluation of mechanical vibration of machines with operating speeds from 600-12,000 RPM as measured on structural members. This group has classified machine systems according to vibrating characteristics in preparation for the development of a group of rotating machinery vibration standards.

S2-77
Vibration Levels of Ships

This group continues to be very active at the international level -- developing standards for measurement and evaluation of shipboard vibration. Specific documents involve a code for the measurement and reporting of shipboard vibration data, code for the measurement and reporting of shipboard local vibration data, and interim guidelines for the evaluation of vibration in merchant ships.

INTERNATIONAL STANDARDS ORGANIZATION COMMITTEE TC108 - Mechanical Vibration and Shock

Meetings of ISO/TC108, its subcommittees and working groups, were held in 1978. The eighth plenary meeting of ISO/TC108 was held on 25 September and 4 October, 1978 in Berlin (German Federal Republic). Twenty-seven delegates representing eleven countries were in attendance at the meetings. During the same period of time meetings were held by ISO/TC108 Subcommittee 1: Balancing, Including Balancing Machines, Subcommittee 2: Measurement and Evaluation of Mechanical Vibration and Shock as Applied to Machines, Vehicles, and Structures, and Subcommittee 3: Use and Calibration of Vibration and Shock Measuring Instruments. In addition, ISO/TC108 Working Groups 1 (Terminology), 4 (Vibration Testing Equipment), 5 (Vibration and Shock Isolators), 8 (Methods of Analyzing and Presenting Vibration and Shock Data), and 11 (Analytical Methods for Assessing the Shock Resistance of Mechanical Systems) held meetings in Berlin. ISO/TC108 Subcommittee 4, Human Exposure to Mechanical Vibration and Shock, held its meeting on September 11-13, 1978, in Czechoslovakia.

TC108 appointed an ad-hoc group to explore the following areas related to mechanical mobility:

- Definition of terms
- Mobility measurements
- Analog and digital analysis
- Methods for parameter identification
- Presentation of mobility data
- Application to modal analysis
- Application to design

The title of TC108/Wg5 was affirmed as "Vibration and Shock Isolators" with its original scope. This limits the work of TC108/Wg5 to the development of standards concerned with the materials, performance, characteristics and methods for testing vibration and shock isolators. An ad-hoc group A was appointed to prepare a statement for a program of work entitled "Damping in Mechanical Systems" which would include the development of standards related to the use of damping in vibration systems, the methods for characterizing damping and evaluating the properties of damping materials and damping in mechanical systems, and the application of

damping materials (as a treatment) to plates and panels in order to minimize their vibratory response. The program of work will include cooperation with other standards organizations (such as ISO/TC61/Wg2/TG12 which is concerned with the characteristics of damping in solid polymers) to ensure that the interests of ISO/TC108 are represented adequately. In response to a request from the European Shock Absorber Manufacturers Association (EUSAMA) for ISO/TC108 to consider developing a standard method of evaluating the in-situ performance of automobile shock absorbers, TC108 appointed an ad-hoc group to consider their request and report back to TC108 before its 1979 meeting. Should sufficient interest be elicited in the SAE and EUSAMA to prepare a program-of-work statement, the ISO member bodies will be canvassed for support and (should it develop) a new TC108 working group will be appointed. TC108 appointed Mr. Pusey to explore the need for standards related to one-time-use, crushable shock isolators. If appropriate, Mr. Pusey will prepare a statement of a program-of-work which will be sent to the member bodies for consideration. A new item of work was proposed - with a scope parallel to the proposed scope of Wg11, except that the method(s) involved would deal with physical testing rather than analysis. TC108 proposed a new item of work in shock testing.

TC108 urged that glossaries of ISO 2041-1975 be prepared in German, Italian, Spanish, Portugese, Danish, Norwegian, Swedish, Dutch, and Japanese, and that they be published by the standards organizations of appropriate member bodies. TC108 Secretariat will communicate the sense of this resolution to the respective member bodies.

Wg4 noted that ISO/DP6070 is now approved by TC108 and will be revised by the TC108 Secretariat. The revised ISO/DP6070 will then be transmitted to the ISO Central Secretariat as a Draft International Standard for Voting by all ISO Member bodies.

It was proposed that there should be a document on the dynamic response of flexible pipe connections (including exhaust trunking for internal combustion engines). This document should take into account the stiffness properties of these connections in three directions as well as the effects of temperature, internal pressure and chemical resistance to the fluid in the pipeline.

The title of Wg11 will be changed to "Analytical Methods for Assessing the Shock Resistance of Mechanical Systems" and the scope of work of ISO/TC108/Wg11 will be responsible for the preparation of basic standards for guidance in assessing shock resistance of mechanical systems (including mechanical models of human systems) in four principal areas applicable to the problem, namely,

- characterization of input(s)
- definition of acceptance criteria
- description of system properties
- selection of analysis methods

TC108 agreed to the formation of TC108/SC1/Wg5 (Secretariat: USA; Convenor: Mr. Stadelbauer) - **Balancing Machines and Safety Enclosures**, with the following scope:

- Review test procedure in ISO2953-1975 in light of proposals submitted by USA under document TC108/SC1N24.
- Prepare recommendations for safety enclosures for balancing machines and rotors.
- Collect and review standards from organizations other than TC108 dealing with balancing and balancing machines.

TC108 agreed to the formation of SC1/Wg8 (Secretariat: DIN" Convener: Mr. Federn) - Review of ISO1940-1973 ***"Balance Quality of Rotating Rigid Bodies"*** - and ***proposal to include flexible rotors*** with the following two-part scope:

- SHORT-RANGE: before the next meeting of SC1, to prepare a revision of ISO1940 which takes into acount the comments received
- LONG-RANGE: to consider the French document (SC1N35) which suggests that a combined rigid- and flexible-rotor document be prepared by SC1

TC108 agreed that a revised document, taking into account comments received, will be forwarded to the ISO Central Secretariat for vote as a Draft International Standard.

With respect to the background paper issued on the areas of necessary cooperation between SC2 and SC4, TC108 agreed to form a Secretariat Steering Committee to address questions related to areas of re-

sponsibility for SC2 and SC4, respectively and jointly.

TC108 approved the following scope for SC3; *Standardization in the field of use and calibration of* mechanical vibration and shock measuring instruments. TC108 noted that SC3 approved document 108/3N34 "Fifth Draft Proposal ISO/DP5348 - Mechanical Mounting of Accelerometers (Seismic Pickups)" as a Draft International Standard which will be transmitted to the ISO Central Secretariat for vote.

Under the approved socpe of work, ISO/TC108 *agreed that it is the only committee within ISO* responsible for formulating methods of measurement and systems of evaluation of vibration and shock generated by different sources and their effect on man and mechanical systems. Other technical committees dealing with problems related to vibration measurement should establish direct contact with ISO/TC108 in order to decide mutually the appropriate method for the establishment of the International Standard concerned. ISO/TC108 shall monitor all Draft Proposals and Draft International *Standards of the ISO and other organizations with* which it maintains liaison and bring to the attention of the ISO Central Secretariat any document which conflicts with scope of work and issued standards of ISO/TC108.

TC108 noted the acceptance of DP4867 on Measurement and Reporting of Shipboard Vibration Data as amended and DP4868 on Measurement and Evaluation of Shipboard Local Vibration Data. The edited *documents shall be given via TC108 Secretariat to* the ISO Central Secretariat for publication as DIS. TC108 agreed that document 108/2N19 revised on Interim Guidelines for the Evaluation and Vibration in Merchant Ships shall be submitted as a Draft Proposal simultaneously to SC2 and to TC108 for vote. Changes in this document may be recommended by the TC108 Secretariat Steering Committee for SC2 and SC4.

TC108 noted the resolutions of the SC4 meeting held in September 1978 in Gottwaldow (CSSR) doc. SC4N67), in particular it noted Resolution No. 1 which it adopted as follows: TC108 noted that after review of comments the edited version of Amendments of ISO2631 (doc. 108/4N66) will be submitted to the ISO Central Secretariat for *publication as a draft amendment to ISO 2631.*

ABSTRACT CATEGORIES

ANALYSIS AND DESIGN

Analogs and Analog Computation
Analytical Methods
Dynamic Programming
Impedance Methods
Integral Transforms
Nonlinear Analysis
Numerical Analysis
Optimization Techniques
Perturbation Methods
Stability Analysis
Statistical Methods
Variational Methods
Finite Element Modeling
Modeling
Digital Simulation
Parameter Identification
Design Information
Design Techniques
Criteria, Standards, and Specifications
Surveys and Bibliographies
Tutorial
Modal Analysis and Synthesis

COMPUTER PROGRAMS

General
Natural Frequency
Random Response
Stability
Steady State Response
Transient Response

ENVIRONMENTS

Acoustic
Periodic
Random
Seismic
Shock
General Weapon
Transportation

PHENOMENOLOGY

Composite
Damping
Elastic
Fatigue
Fluid
Inelastic
Soil
Thermoelastic
Viscoelastic

EXPERIMENTATION

Balancing
Data Reduction
Diagnostics
Equipment
Experiment Design
Facilities
Instrumentation
Procedures
Scaling and Modeling
Simulators
Specifications
Techniques
Holography

COMPONENTS

Absorbers
Shafts
Beams, Strings, Rods, Bars
Bearings
Blades
Columns
Controls
Cylinders
Ducts
Frames, Arches
Gears
Isolators
Linkages
Mechanical
Membranes, Films, and Webs
Panels
Pipes and Tubes
Plates and Shells
Rings
Springs
Structural
Tires

SYSTEMS

Absorber
Acoustic Isolation
Noise Reduction
Active Isolation
Aircraft
Artillery
Bioengineering
Bridges
Building
Cabinets
Construction
Electrical
Foundations and Earth
Helicopters
Human
Isolation
Material Handling
Mechanical
Metal Working and Forming
Off-Road Vehicles
Optical
Package
Pressure Vessels
Pumps, Turbines, Fans, Compressors
Rail
Reactors
Reciprocating Machine
Road
Rotors
Satellite
Self-Excited
Ship
Spacecraft
Structural
Transmissions
Turbomachinery
Useful Application

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Fir St., Ann Arbor, MI; U.S. Patents from the Commissioner of Patents, Washington, D.C. 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

ABSTRACT CONTENTS

All abstracts from the Shock and Vibration Bulletin are Proceedings of the 48th Shock and Vibration Symposium which was held in Huntsville, AL on October 18-20, 1978 and sponsored by the Shock and Vibration Information Center, Washington, D.C.

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ANALYSIS AND DESIGN

ANALYTICAL METHODS

(Also see No. 43)

79-1

Research Method of the Eigenmodes and Generalized Elements of a Linear Mechanical Structure

R. Fillod and J. Piranda

Laboratoire de Mécanique Appliquée, associé au C.N.R.S., Besancon, France, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 3, pp 5-12 (Sept 1978) 5 figs, 10 refs

Key Words: Natural frequencies, Normal modes, Linear systems

The determination of the eigenfrequencies, eigenmodes and generalized elements of a structure is fundamental in the study of its dynamic behavior (e.g. fluttering of planes). Of all the methods tested, those based on the appropriation of modes seem to give the most accurate results. The method presented in this paper is based on the appropriation method and permits determination of the eigenvectors and generalized elements directly by calculus from the forced responses to a given frequency.

79-2

Time Delay Bias Errors in Estimating Frequency Response and Coherence Functions

A.F. Seybert and J.F. Hamilton

Dept. of Mech. Engrg., Univ. of Kentucky, Lexington, KY 40506, J. Sound Vib., 60 (1), pp 1-9 (Sept 8, 1978) 5 figs, 11 refs

Key Words: Error analysis, Signal processing techniques, Time-dependent parameters

This paper discusses the problem of bias errors introduced when frequency response and coherence functions are estimated for systems in which a time delay is present. Theory is developed showing the dependence of the bias errors on the time delay, the bandwidth and the length of the sample record of the input/output processes. Two experiments were designed to check the theory. In one experiment a loudspeaker, driven by white noise, and a microphone were used. In a second experiment a tape recorder was used with a fixed spacing between the record/playback heads to introduce a time delay. For both experiments, comparison with theory was good.

79-3

An Algorithm for the Multivariate Spectral Analysis of Linear Systems

T.M. Romberg

Engrg. Res. Div., Australian Atomic Energy Commission Res. Establishment, Lucas Heights, New South Wales 2232, Australia, J. Sound Vib., 59 (3), pp 395-404 (Aug 8, 1978) 5 figs, 10 refs

Key Words: Spectrum analysis, Linear systems, Algorithms

A computational algorithm is presented for the multivariate spectral analysis of linear systems. A review is given of traditional formulations for the partial spectral density, transfer and coherence functions. They are more efficiently evaluated by manipulating the system spectral (augmented) matrix with a simple recurrence equation. The computational procedures for performing the relevant calculations are discussed in detail, and to demonstrate the advantages of the present method the two-phase flow stability of a heated channel is identified from hydrodynamic and vibration measurements.

79-4

Development of a Finite Dynamic Element for Free Vibration Analysis of Two-Dimensional Structures

K.K. Gupta

Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, Intl. J. Numer. Methods Engr., 12 (8), pp 1311-1327 (1978) 4 figs, 1 table, 7 refs

Key Words: Free vibration, Finite element technique

The paper develops an efficient free-vibration analysis procedure of two-dimensional structures. This is achieved by employing a discretization technique based on a recently developed concept of finite dynamic elements, involving higher order dynamic correction terms in the associated stiffness and inertia matrices. A plane rectangular dynamic element is developed in detail. Numerical solution results of free-vibration analysis presented herein clearly indicate that these dynamic elements combined with a suitable quadratic matrix eigenproblem solution technique effect a most economical and efficient solution for such an analysis when compared with the usual finite element method.

79-5
The K-Quotient
A.B. Ku
Dept. of Civil Engrg., Univ. of Detroit, Detroit, MI 48221, J. Sound Vib., 60 (1), pp 63-69 (Sept 8, 1978) 4 tables, 7 refs

Key Words: Eigenvlaue problems

The Rayleigh Quotient and a recently proposed Timoshenko Quotient are upper bounds to the fundamental eigenvalue of a discrete dynamic system. In the present paper, a new quotient is presented. This quotient does not require the closeness of the trial vector to the eigenmode and its accuracy is improvable by raising the numerical value of the parameter p.

OPTIMIZATION TECHNIQUES

79-6
Optimality Criterion Techniques Applied to Mechanical Design
M.R. Khan, W.A. Thornton, and K.D. Willmert
Clarkson College of Technology, Potsdam, NY, J. Mech. Des., Trans. ASME, 100 (2), pp 319-327 (Apr 1978) 8 figs, 9 tables, 22 refs

Key Words: Optimization, Minimum weight design, Natural frequencies

Presented are two optimality criterion techniques for the minimum weight design of mechanical and structural systems subject to limitations on stresses and natural frequencies. The results, based on their application to several examples, are compared with those obtained by other researchers and with standard nonlinear mathematical programming techniques, as well as with a special linear approach.

FINITE ELEMENT MODELING

(See No. 121)

MODELING

79-7
Adjustment of a Conservative Non Gyroscopic Mathematical Model from Measurement
L. Bugeat, R. Fillod, G. Lallement, and J. Piranda
Laboratoire de Mécanique Appliquée, associé au C.N.R.S., Faculté des Sciences de Besancon, France, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 3, pp 71-81 (Sept 1978) 5 refs

Key Words: Mathematical models, Parameter identification technique

A method of calculating the modifications of a discrete, conservative model, which enables one to reduce the distance between its dynamic behavior and the one identified on the physical structure is presented. An initial approximate model is known and results from a discretization "a priori" for example by finite element method. The results of a numerical simulation are presented.

79-8
Laguerre Function Representation of Transients
G.R. Spalding
Wright State University, Dayton, OH, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 1, pp 137-141 (Sept 1978) 4 figs, 4 refs

Key Words: Dynamic response, Damped structures, Mathematical models

This paper discusses Laguerre functions and their use in modeling the dynamic response of highly damped systems. Laguerre functions of varying time constant are generated from the Laguerre polynomials. By sampling at the axis crossings of the nth order Laguerre polynomial, system response can be represented by a finite set of orthonormal vectors. These vectors provide both a representation that is exact at the measurement points and interpolation functions that can be suited to the application.

PARAMETER IDENTIFICATION

79-9
Frequency Domain Structural Parameter Estimation
W.F. Krieger
Ph.D. Thesis, Purdue Univ., 180 pp (1977)
UM 7813076

Key Words: Frequency domain, Parameter identification technique

A new methodology for estimating structural parameters recursively in the frequency domain is developed. Maximum likelihood and Bayesian estimates are obtained, as are the appropriate confidence regions. A computer simulation example is carried out so that the performance of the new methodology can be evaluated.

79-10

Mechanical System Identification and Decomposition by Dynamic Data System Methodology

E. Garcia-Gardea

Ph.D. Thesis, The Univ. of Wisconsin-Madison, 254 pp (1978)

UM 7811722

Key Words: System identification technique, Dynamic data system technique, Stochastic processes

The identification of mechanical systems is necessary in order to better analyze and control the system's behavior. Existing identification approaches either involve postulating a mathematical model based on first principles or employ experimental techniques such as frequency response having both advantages and disadvantages. This thesis uses a new approach called Dynamic Data System (DDS) methodology for mechanical system identification and decomposition. The DDS methodology considers the stochastic nature of operational data and develops physically meaningful stochastic difference/differential equations.

DESIGN INFORMATION

79-11

Engineering Design Handbook Computer Aided Design of Mechanical Systems. Part Two

E.J. Haug and J.S. Arora

Army Materiel Development and Readiness Command, Alexandria, VA, Rept. No. DARCOM-P, 706-193, 538 pp (Sept 1977)

AD-A055 008/7GA

Key Words: Design techniques, Computer-aided techniques, Mechanical systems, Manuals and handbooks

This handbook consists of in-depth treatments of several specific classes of design problems, employing and advancing the theoretical development and initial structural applications of AMCP 706-192. The approach taken is to treat problems that fall in fields such as fail safe structural design, structural dynamics optimization, contact analysis and design, and vehicle suspension design in enough depth that advanced system designers can follow through a relatively realistic design problem. It is hoped that this set of examples also will motivate accelerated application of techniques for mechanical design optimization.

SURVEYS AND BIBLIOGRAPHIES

79-12

Crashworthiness of Motor Vehicles. A Subject Bibliography from Highway Safety Literature

L. Flynn

Technical Services Div., National Highway Traffic Safety Admin., Washington, D.C., Rept. No. DOT-HS-803 241, 211 pp (Mar 1978)

PB-281 716/1GA

Key Words: Bibliography, Collision research (automotive)

The bibliography represents literature acquired since the establishment of the National Highway Traffic Safety Administration (NHTSA) as related to the crashworthiness of motor vehicles. It is comprised of NHTSA contract reports, reports of other organizations concerned with highway safety, and articles from periodicals in related fields.

79-13

Soil Structure Interactions (A Bibliography with Abstracts)

G.E. Habercom, Jr.

National Technical Information Service, Springfield, VA, 116 pp (July 1978)

NTIS/PS-78/0717/5GA

Key Words: Bibliographies, Interaction: soil-structure, Tunnels, Pipes (tubes), Pile structures, Hardened installations

Interactions resulting from loads exerted on soils and structures are reviewed. Such diversified structures as tunnels, conduits, pipes, piles, hardened installations, and plow blades are covered. Loads resulting from nuclear explosions as well as physical loads are investigated. Earthquake contributing loads are excluded.

MODAL ANALYSIS AND SYNTHESIS

(Also see Nos. 78, 79, 80, 104)

79-14

Load Transformation Development Consistent with Modal Synthesis Techniques

R.F. Hruda and P.J. Jones

Martin Marietta Corp., Denver, CO, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 1, pp 103-109 (Sept 1978) 6 figs, 1 table, 1 ref

Key Words: Modal synthesis

A method is presented for the development of component internal load transformations consistent with modal synthesis procedures. The resulting load transformations account for component interactions across statically indeterminate interfaces. A unique approach of obtaining these transformations is presented which, for large systems, would be economical. Further, a modified modal coupling procedure is employed which offers advantages over previous techniques.

79-15

Reduced System Models Using Modal Oscillators for Subsystems (Rationally Normalized Modes)

R.H. Wolff and A.J. Molnar

Westinghouse R&D Center, Pittsburgh, PA 15235, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 1, pp 111-118 (Sept 1978) 6 figs, 4 refs

Key Words: Modal models, Mathematical models

This paper develops a method of using modal oscillators to represent complex structural subcomponents which can be applied to unidirectional models.

79-16

A Building Block Approach to the Dynamic Behavior of Complex Structures Using Experimental and Analytical Modal Modeling Techniques

J.C. Cromer, M. Lalanne, D. Bonnecase, and L. Gaudriot

Institut National des Sciences Appliquées, Villeurbanne, France, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 1, pp 77-91 (Sept 1978) 14 figs, 4 tables, 27 refs

Key Words: Modal models, Building block approach

In the case of complex structures whose equations of motion cannot be obtained directly, even by finite element techniques, it may be possible to get their potential and kinetic energies from experiments. A building block approach taking into account constrained or unconstrained substructures is used. Components whose properties are determined by experiments are connected to those modeled by finite element techniques. In connection with theoretical formulations, experimental devices and procedures are presented. A new transfer function analyzer system has been used. The constrained and unconstrained modal methods are applied first to a beam in bending in order to point out the experimental aspects of these techniques. The methods are then applied to a complex practical structure and agreement between experimental and theoretical results is shown to be good.

COMPUTER PROGRAMS

GENERAL

(Also see Nos. 84, 123)

79-17

Stiffness and Flexibility Element for SAP4

D.W. Coats

Lawrence Livermore Lab., California Univ., Livermore, CA, Rept. No. UCID-17654, 7 pp (Oct 27, 1977)

N78-25471

Key Words: SAP (computer program), Stiffness methods, Flexibility methods

A stiffness and flexibility element was added to the SAP4 program. Direct input of a member stiffness or member flexibility matrix is now possible. This element is used to reduce significantly the number of degrees of freedom in a large mathematical model by presenting a portion or portions of the structure with one or more of these elements.

79-18

A Source of Large Errors in Calculating System Frequencies

R.M. Mains

Dept. of Civil Engrg., Washington Univ., St. Louis, MO, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 3, pp 1-4 (Sept 1978) 1 fig, 3 tables

Key Words: Error analysis, Computer programs, Natural frequencies

Attention is called to errors in system frequency calculations resulting from the use of non-diagonal mass matrices with eigenvalue routines that replace the mass matrix with its eigenvalues before proceeding to the calculation of system frequencies. The errors are illustrated in several different solutions of an 18 degree-of-freedom system. How to avoid these errors is presented.

79-19

Helicopter Transmission Vibration and Noise Reduction Program. Volume II. User's Manual

J.J. Sciarra, R.W. Howells, J.W. Lenski, Jr., and

R.J. Drago
Boeing Vertol Co., Philadelphia, PA, Rept. No. D210-11236-2, USARTL-TR-78-2B, 431 pp (Mar 1978)
AD-A054 827/1GA

Key Words: Computer programs, Manuals and handbooks, Power transmission systems, Helicopter engines, Vibration control, Noise reduction

The objective of the Helicopter Transmission Vibration/Noise Reduction Program was to generate analytical tools for the prediction and reduction of helicopter transmission vibration/noise that provide the capability to perform trade studies during the design stage of a program. The work conducted under this program is highly computer-oriented and makes extensive use of several computer programs as indicated in the technical report (Volume 1). This User's Manual describes these computer programs, presents rationale for their use, and discusses their application.

79-20

A Compact Computer Program for Calculating Buckling Stresses and Natural Frequencies of Vibration of Prismatic Plate Assemblies

F.W. Williams and C.J. Wright
Dept. of Civil Engrg. and Bldg. Tech., UWIST, Cardiff, UK, Intl. J. Numer. Methods Engr., 12 (9), pp 1429-1456 (1978) 6 figs, 1 table, 8 refs

Key Words: Computer programs, Plates, Natural frequencies

Low cost and increasing capability favor the use of minicomputers as design tools. The 336 statement Fortran program which is listed and explained was developed to use such small computers efficiently. It calculates the buckling stresses, or the natural frequencies of vibration, of prismatic assemblies of longitudinally compressed isotropic plates.

79-21

A Digital Computer Program for the Dynamic Interaction Simulation of Controls and Structure (DISCOS). Volume 1

C.S. Bodley, A.D. Devers, A.C. Park, and H.P. Frisch
Goddard Space Flight Center, NASA, Greenbelt, MD, Rept. No. NASA-TP-1219-Vol-1, G7702-F26-Vol-1, 169 pp (May 1978)
N78-25123

Key Words: Computer programs, Digital techniques, Spacecraft, Attitude control systems

A theoretical development and associated digital computer program system for the dynamic simulation and stability analysis of passive and actively controlled spacecraft are presented. The dynamic system (spacecraft) is modeled as an assembly of rigid and/or flexible bodies not necessarily in a topological tree configuration. The computer program system is used to investigate total system dynamic characteristics, including interaction effects between rigid and/or flexible bodies, control systems, and a wide range of environmental loadings. In addition, the program system is used for designing attitude control systems and for evaluating total dynamic system performance, including time domain response and frequency domain stability analyses.

ENVIRONMENTS

ACOUSTIC

(Also see Nos. 62, 73, 77, 146, 147, 160)

79-22

Mirror Image Method of Analyzing the Combined Effect of Barriers and Absorbing Surfaces in Industrial Interiors and Apartments

S. Czarnecki
Inst. of Fundamental Technological Res., Polish Academy of Sciences, Swietokrzyska 21, 00-049 Warsaw, Poland, Noise Control Engr., 11 (1), pp 18-30 (July/Aug 1978) 12 figs, 13 refs

Key Words: Noise barriers, Industrial facilities

The effectiveness of barriers in the interiors of industrial buildings is generally very low because of the influence of reflected waves. The author discusses the advantage of using both barriers and absorbing belts placed over the barriers and presents the calculation method and measurements with models as well as real, full-scale situations.

79-23

Single Screen Noise Barrier

R.N. Foss
Applied Physics Lab., 1013 N.E. Fortieth St., Seattle, WA 98105, Noise Control Engr., 11 (1), pp 40-44 (July/Aug 1978) 10 figs, 3 refs

Key Words: Noise barriers, Sound transmission

A series of experimental measurements was conducted to

determine the effect of barrier screens on the transmission of sound from a point source. Procedures and results of this research are analyzed.

79-24

Roadside Barrier Effectiveness, Noise Measurement Program

E.J. Rickley, U. Ingard, Y.C. Cho, and R.W. Quinn
Transportation Systems Ctr., Cambridge, MA, Rept. No. DOT-TSC-NHTSA-78-24, DOT-HS-803 289, 240 pp (Apr 1978)
PB-282 045/4GA

Key Words: Noise barriers, Acoustic linings, Noise measurement

A field noise measurement program was conducted to assess the performance of a variable height highway noise barrier with and without an acoustic lining material. The barrier site on Interstate I-93 in Andover MA was located adjacent to an acoustically similar unobstructed site. The noise emissions from a common stream of vehicular traffic were measured at both sites simultaneously and compared to evaluate the performance of the barrier. A 1000-foot-long barrier at effective heights of 2.8, 6.8, 10.8 and 14.8 feet was measured and evaluated. Included in the report is the statistical noise data from fourteen measuring systems for each barrier configuration along with spectral data, traffic information and meteorological conditions.

79-25

Self-Excited Depth-Mode Resonance for a Wall-Mounted Cavity in Turbulent Flow

S.A. Elder
Physics Dept., U.S. Naval Academy, Annapolis, MD 21402, J. Acoust. Soc. Amer., 64 (3), pp 877-890 (Sept 1978) 16 figs, 3 tables, 52 refs

Key Words: Helmholtz resonators

Experimental and theoretical results are presented for a wall-mounted cavity in turbulent flow, oscillating at Helmholtz or depth-mode resonance, where the mouth dimensions are small compared with acoustic wavelength. A new, computerized, hot-wire method was employed to investigate the oscillating flow field in the cavity mouth. Measured wavelength of the interface wave agrees well with predictions of Michalke, using an equivalent laminar flow model based on the oscillating mean velocity profile. By means of a forward transfer function derived from the theoretical interface wave model and a backward transfer function derived from organ-pipe theory, a root locus solution of the frequency lock-in problem has been obtained. Predicted frequencies and sound pressure amplitudes are in good agreement with experimental values at the lower modes. Both resonant and off-resonant oscillation was investigated.

79-26

A Note on Nonlinear Acoustic Resonances in Rectangular Cavities

J.J. Keller
Brown Boveri Res. Centre, CH-5405, Baden, Switzerland, J. Fluid Mech., 87 (2), pp 299-303 (July 26, 1978) 1 fig, 6 refs

Key Words: Cavity resonators, Acoustic resonators

The problem of the resonant response of a gas contained in a two-dimensional rectangular cavity to periodic (sinusoidal) velocity excitations at the walls of the cavity is investigated. It is found that is some neighborhood of each resonant frequency there are discontinuous pressure disturbances (shock waves). The present theory is an extension of Chester's theory on resonances in closed tubes.

79-27

Subjective Loudness of Sonic-Boom: N-Wave and Minimized (Low-Boom) Signatures

A. Niedzwiecki and H.S. Ribner
Toronto Univ., Ontario, Canada, Rept. No. UTIAS-TN-215; CN-ISSN-0082-5263, 27 pp (Nov 1977)
N78-24896

Key Words: Sonic boom, Acoustic properties

A loudspeaker-driven simulation booth with extended rise-time capability (down to 0.22 ms) was used for subjective loudness tests of sonic booms. Test series 1 compared N-waves over a range of 0.22 to 10 ms rise time, 100 to 250 ms duration and 0.5 to 2.0 psf (24 to 96 N/sqm) peak overpressure. Tradeoff between rise time and overpressure was measured for equal loudness, as well as the tradeoff between duration and overpressure. Test series 2 compared certain flat-top sonic boom signatures with a reference N-wave (0.5 psf, 1 ms rise time, 150 ms duration).

79-28

Underwater Acoustic Properties of Cork-Rubber

H.A.J. Rijnja
Physics Lab., RVO-TNO, The Hague, Netherlands, Rept. No. PhL-1977-16; TDCK-69188, 45 pp (Apr 1977)
N78-26885

Key Words: Underwater sound, Acoustic absorption, Rubber

The ability of cork-rubber compounds to absorb sound under water is well known, but generally this property varies strongly with hydrostatic pressure. A large number of different compositions was investigated, leading to the discovery of materials superior to others as a sound absorbing material in electroacoustic transducers for deep submergence.

79-29

Transmission Characteristics of Sound Pulse Through Circular Plate

I. Nakayama, A. Nakamura, and R. Takeuchi
Inst. of Scientific and Industrial Res., Osaka Univ., Yamadakami, Suita, Osaka 565, Japan, Acustica, 40 (1), pp 40-45 (May 1978) 7 figs, 7 refs

Key Words: Sound waves, Hole-containing media, Plates

Measurements are made of the radiation field of a single sound pulse through a circular aperture in a wall and also through a thin metal plate clamped on a baffle when the pulse impinges perpendicularly. The radiated waveforms are simulated by the Fourier transformation under the assumption of the piston motion of the air and of the plate at the boundary. The insulation characteristics of the plate for a single sound pulse in the far-field are evaluated.

79-30

Amplitude - Dependent Attenuation of Acoustic Shock Pulses in Aluminum Rod

Y. Yasumoto, A. Nakamura, and R. Takeuchi
Inst. of Scientific and Industrial Res., Osaka Univ., Osaka, Japan, Acustica, 39 (5), pp 307-315 (Apr 1978) 12 figs, 4 tables, 6 refs

Key Words: Acoustic absorption, Shock excitation, Rods

Experimental study is made of the attenuation characteristic dependency on amplitude of acoustic shock pulses propagating in aluminum rods. Attenuation constants are measured as a function of the peak values of stress and strain of the shock pulses in the aluminum rods before and after annealing at various temperatures. A discussion is given of the microscopical and macroscopical hysteresis loss by means of the stress-strain relationship for shock pulses.

79-31

Nonlinear and Parametric Phenomena in Dispersive Acoustic Systems

L.A. Ostrovsky, I.A. Soustova, and A.M. Sutin
Radiophysical Res. Inst., Gorky, USSR, Acustica, 39 (5), pp 298-306 (Apr 1978) 10 figs, 14 refs

Key Words: Acoustic radiation, Acoustic properties, Elastic waves, Waveguide analysis, Resonators

Some results of the theoretical and experimental investigations of the dispersion nonlinear acoustics phenomena in acoustic waveguides and resonators are discussed. In such systems the dispersion provides the possibility of resonant energy transformation between different modes at selected frequencies. The following processes are considered: parametric amplification of traveling waves in waveguides, parametric generation of sound (PGS) in resonators with fluid and ring solid-state resonators; auto-modulation of intensive sound; multifrequency processes including a quasi-noise generation; propagation of stationary acoustic pulses (elastic solutions) in solid rods and peculiarities of their dissipation.

PERIODIC

(See No. 43)

RANDOM

(Also see Nos. 82, 148)

79-32

Incandescent Lamp Life Under Random Vibration

C.J. Beck, Jr.
Boeing Aerospace Co., Seattle, WA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 71-81 (Sept 1978) 10 figs, 9 tables, 5 refs

Key Words: Lamps, Random vibration, Testing techniques

Several sets of incandescent lamps were subjected to random vibration in order to generate a curve of lamp life versus vibration level. Each set of lamps was vibrated until all lamps failed or for a maximum time of 2-1/2 hours. The tests were conducted with lamps energized and not energized.

79-33

Fracture Mechanics Applied to Step-Stress Fatigue Under Sine/Random Vibration

R.G. Lambert
General Electric Co., Utica, NY 13503, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 3, pp 93-101 (Sept 1978) 9 figs. 1 table, 7 refs

Key Words: Fatigue life, Random vibration

A proposed cumulative fatigue damage law is derived which uses fracture mechanics theory as its basis in order to predict the fatigue life of structures subjected to several levels of sequentially applied stress. The proposed law applies to all initial crack (i.e., flaw) sizes in the structure. The proper boundary condition to be imposed at the interface of the two stress regions is analyzed.

79-34

First-Passage Failure Probability in Random Vibration of Structures with Random Properties

N. Nakagawa, R. Kawai, and K. Funahashi

Faculty of Engrg., Kobe Univ., Kobe, Japan, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 3, pp 83-92 (Sept 1978) 1 fig, 4 refs

Key Words: Failure analysis, Probability theory, Random vibration

The first-passage failure problem is treated in random vibration of structures with damping, considered as a random variable. First, nonstationary responses are generally analyzed for random vibration of structures, which have random properties. Using the derivative method, statistical values of responses (mean function and autocovariance function) are obtained. Thereafter, the first-passage failure probability is considered.

79-35

The Business Machine Vibration Environment

D.W. Skinner and J.L. Zable

IBM Corporation, J. Environ. Sci., 21 (5), pp 16-21 (Sept/Oct 1978) 15 figs, 6 refs

Key Words: Equipment response, Vibration excitation

Data is presented which depicts the vibration environment of business machines in the functional state. Data also is presented on the shipping environment. The data is discussed as to the nature of the vibration and the effects of the machine/environment interaction. An analytical model is developed and discussed.

SEISMIC

(Also see Nos. 138, 139, 163)

79-36

Response Analysis of 500KV Circuit Breaker with Nonlinear Damping Devices Under Seismic Excitation

S. Fujimoto, T. Shimogo, and M. Arii

Keio Univ., Yokohama, Japan, Bull. JSME, 21 (157), pp 1103-1112 (July 1978) 20 figs, 6 refs

Key Words: Seismic excitation, Nonlinear damping, Transmission lines, Random excitation

This paper deals with a fundamental research for the aseismic design of a 500KV air circuit breaker. In particular, effects of nonlinearity of the damping device, which is connected to stays, on the seismic response of the circuit breaker are theoretically investigated.

79-37

Nonlinear Analysis of Reinforced Concrete Planar Structures Subject to Monotonic, Reversed Cyclic and Dynamic Loads

A.B. Agrawal

Ph.D. Thesis, The Univ. of New Brunswick, Canada (1977)

Key Words: Reinforced concrete, Dynamic response, Nonlinear analysis, Finite element technique, Seismic excitation

This thesis is concerned with the incremental nonlinear analysis of reinforced concrete planar structures subject to monotonically increasing, reversed cyclic and dynamic (seismic) loadings. The proposed analytical model is based on the finite element method. Both plain concrete and steel reinforcement are idealized as elasto-plastic materials. The formulation is first applied to trace the load-deflection response of shear panels and coupling beams under monotonic and reversed cyclic loads, and to a shear wall subject to load reversals. The results compare favorably with available experimental data.

SHOCK

(Also see Nos. 12, 27, 49, 151, 152, 153, 193)

79-38

Propagation of a Hyperdetonation Shock Wave in a Nonhomogeneous Medium

S. Kaliski

Inst. of Plasma Physics and Laser Microfusion, P.O. Box 49, 00-908, Warsaw, 49 Poland, Bull. Acad. Polon. Sci., Ser. Sci. Tech., 26 (4), pp 75-81 (1978) 4 figs, 7 refs

Key Words: Shock wave propagation

The simple approximate formulae which have been obtained allow appraisal of the velocity of a hyperdetonation shock

wave front (the velocity of particles at the wave front) in a nonhomogeneous body of decreasing density.

79-39

Research on Shock Wave-Turbulent Boundary Layer Interaction

J. Delery

European Space Agency, Paris, France, Rept. No. ESA-TT-476, pp 31-61 (May 1978)(Engl. transl. of La Rech. Aerospatiale, Bull. Bimestriel, Paris, No. 1977-6, pp 337-348 (Nov-Dec 1977)

N78-25362

Key Words: *Shock waves, Turbulence*

Interaction phenomena between shock waves and turbulent boundary layers are of major importance in transonic flow. Coupling methods which exist at present to solve this problem depend on an accurate description of the behavior of the boundary layer across a shock. Research at ONERA covers a wide range of Reynolds numbers. The systematic examination of the results has led to the development of a semi-empirical method which gives a fairly good representation of the thickening of the boundary layer during the interaction.

79-40

Impedance Techniques for Scaling and for Predicting Structure Response to Air Blast

F.B. Safford, R.E. Walker, and T.E. Kennedy

Agbabian Associates, El Segundo, CA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 193-214 (Sept 1978) 28 figs, 3 tables, 9 refs

Key Words: Air blast, Structural response, Scaling, Prediction techniques, Impedance

Transfer impedances were measured on a 1/12-scale model and on its prototype structure. The structure was the Perimeter Acquisition Radar Building (PARB) of the SAFEGUARD ABM System. The impedance measurements for both structures were then used with air-blast loads to predict internal acceleration responses.

79-41

A Non-Contacting Beta Backscatter Gage for Explosive Quantity Measurement

P.B. Higgins, F.H. Mathews, and R.A. Benahm

Sandia Laboratories, Albuquerque, NM, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 113-126 (Sept 1978) 14 figs, 1 table, 6 refs

Key Words: Explosions, Blast loads, Measurement techniques

A non-contacting method of measuring the quantity of light-initiable explosive previously applied to a surface is described. Design parameters, calibration procedures and field results are given for a beta backscatter gage which measures the areal density of a layer of the primary explosive, silver acetylide-silver nitrate (SASN), on a carbon or aluminum sub-surface. The "radiation patterns" produced by the gage using three different beta source geometries were determined and their relative merits are discussed.

79-42

Seismic Ground Motion from Free-Field and Underburied Explosive Sources

J.T. Cherry, T.G. Barker, S.M. Day, and P.L. Coleman

Systems Science and Software, La Jolla, CA, Rept. No. SSS-R-77-3349, 51 pp (July 1977)

AD-A055 141/6GA

Key Words: Underground explosions, Nuclear explosions, Ground motion, Experimental results, Mathematical models

Small-scale laboratory experiments were conducted and analyzed to study the effect of the proximity of the free surface on the seismic ground motions. Two classes of experiments were done. In one the charges were far from the free-surface and the free-field displacement-time histories were measured. In the second class the charges were near the surface and were either fully contained or formed a crater. The calculations are in good agreement with the laboratory data, providing verification of both the constitutive models and the methods.

79-43

Response to Moving Loads Over a Crystalline Half-Space

S. De

Old Engineering Office (Qrs.), Santiniketan, Birbhum, West Bengal, India, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 3, pp 63-70 (Sept 1978) 1 fig, 13 refs

Key Words: Periodic response, Ground motion, Nuclear explosions, Wave propagation

The mathematical analysis to study the steady-state response to a line load moving with a constant speed over a crystalline half-space is considered. The half-space is supposed to be composed of monoclinic, orthorhombic and cubic crystals. The solutions for the cases of supersonic, subsonic and transonic are investigated.

79-44

Workbook for Estimating Effects of Accidental Explosions in Propellant Ground Handling and Transport Systems

W.E. Baker, J.J. Kulesz, R.E. Ricker, P.S. Westine, V.B. Parr, L.M. Vargas, and P.K. Moseley

Southwest Res. Inst., P.O. Box 28510, San Antonio, TX 78284, Rept. No. NASA CR-3023, 273 pp (Aug 1978)

Key Words: Propellants, Explosion effects, Underground structures, Underground explosions

This workbook is a supplement to an earlier NASA publication, NASA CR-134906, which is intended to provide the designer and safety engineer with rapid methods for predicting damage and hazards from explosions of liquid propellant and compressed gas vessels used in ground storage, transport, and handling. Topics covered in various chapters are Estimates of explosive yield, Characteristics of pressure waves, Effects of pressure waves, Characteristics of fragments, and Effects of fragments and related topics.

79-45

Finite Element Analysis of Multicomponent Structures in Rigid Barrier Impacts

J.K. Gran, L.E. Schwer, J.D. Colton, and H.E. Lindberg

SRI International, Menlo Park, CA., Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 153-160 (Sept 1978) 12 figs, 3 refs

Key Words: Guardrails, Impact response, Finite element technique

Techniques are presented for the transient analysis of multicomponent structures impacting rigid barriers using the finite element method. The analysis considers distortion and failure of joints, multiple impacts, and elastic-plastic material behavior. The models for each component of an example structure are developed separately, guided by the results of impact experiments. A comparison of the predictions of these finite element models with the results of the experiments demonstrates the applicability and accuracy of the models. The complete structure is then analyzed by combining the component models. The result is good correlation of experiment and analytical prediction for the acceleration of a mass on a rather complex structure.

79-46

Frequency Response and Differentiation Requirements for Impact Measurements

A.S. Hu and H.-T. Chen

Physical Science Lab., New Mexico State Univ., Las Cruces, NM 88003, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 123-130 (Sept 1978) 8 figs, 4 refs

Key Words: Impact response (mechanical), Harmonic analysis

Impact response data are often subjected to integration and differentiation procedures. These procedures are low- and high-pass filtering processes. This paper discusses the measurement frequency response requirements using harmonic analysis and shows how these requirements are related to three differentiation procedures.

79-47

On the Impact End in Longitudinal Dynamic Plastic Wave Propagation

D.W. Nicholson and A. Phillips

Dept. of Engrg. and Applied Science, Yale Univ., New Haven, CT 06528, Acta. Mech., 29, pp 75-92 (1978) 13 refs

Key Words: Impact shock, Shock waves, Wave propagation, Rods, Laplace transformation

Several different dynamic plastic constitutive models are considered, using longitudinal wave propagation in semi-infinite rods. Both stress impact and velocity impact are treated. The Laplace Transform is used, and near the impact end the solution is obtained in terms of familiar special functions.

79-48

Bird Impact Loading

J.S. Wilbeck and J.P. Barber

Air Force Materials Lab., Wright Patterson AFB, OH, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 115-122 (Sept 1978) 6 figs, 8 refs

Key Words: Bird strikes, Experimental data, Impact load prediction

An extensive experimental program was undertaken to investigate the mechanics of bird impact and to define the loads which birds exert at impact. Bird impact pressures were measured by impacting birds against a heavy steel plate in which piezoelectric transducers were flush mounted. The experimental data is presented and compared with the predictions of a fluidynamic theory.

GENERAL WEAPON

79-49
Probabilistic Failure Analysis of Lined Tunnels in Rock
D.A. Evensen and J.D. Collins
J.H. Wiggins Co., Redondo Beach, CA., Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 215-231 (Sept 1978) 11 figs, 2 tables, 13 refs

Key Words: Linings, Tunnels, Nuclear explosion effects

A study was performed to develop a methodology for planning of nuclear underground tests such that the negative impact of the uncertainty in the free-field weapons effects and the structure capabilities would be minimized. The paper discusses how to guide the design of the structures to maximize the acquisition of good data, and the methodology could be directly applicable to future nuclear tests.

79-50
Some Dynamic Response Environmental Measurements of Various Tactical Weapons
W.W. Parmenter
Naval Weapons Center, China Lake, CA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 151-158 (Sept 1978) 18 figs, 11 refs

Key Words: Weapons systems, Dynamic response, Measurement techniques

This paper reports on pertinent results of several environmental dynamic measurement programs for widely diverse types of tactical weapons. Included are spectra for the SLUFAE weapon mounted on a tracked vehicle, the ASROC missile mounted within launcher cells and magazines of various classes of ships, the FAE-II and GATOR free-fall weapons captive-flown on A-7 and AV-8 aircraft, the Condor weapon captive-flown on an A-6 aircraft, and the MAD-FAE weapon dispenser system suspended beneath a CH-53 helicopter. The character of the dynamic environments during weapon deployment is briefly discussed.

TRANSPORTATION

(See No. 166)

PHENOMENOLOGY

COMPOSITE

79-51
Proceedings of the 9th ICAF Symposium: Fatigue Life of Structures Under Operational Loads
O. Buxbaum and D. Schuetz
Laboratorium f. Betriebsfestigkeit, Darmstadt, West Germany, Rept. No. LBF-TR-136 (1977); ICAF-960, 644 pp (1977)
N78-24571

Key Words: Fatigue life, Composite material, Aircraft

The National Aeronautics and Space Administration has conducted research during the past decade to demonstrate the viability and desirability of using composites, principally for civil aircraft. Similar research under sponsorship of the Department of Defense has been in progress to exploit these materials for military aircraft systems. Some of the NASA programs are outlined and examples are given of structural improvements which have been demonstrated. An evaluation is also given on complementary research to create the technology needed to design composite structures with confidence.

DAMPING

(Also see No. 97)

79-52
Damping of an Engine Exhaust Stack
J.J. DeFelice and A.D. Nashif
Sikorsky Aircraft Div. of United Technology Corp., Stratford, CT 06602, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 75-84 (Sept 1978) 14 figs, 1 table, 6 refs

Key Words: Material damping, Helicopter engines, Exhaust systems, Fatigue life

This paper describes a program whose objective was to introduce high damping into the helicopter engine exhaust extension in order to decrease its vibrational amplitude at resonance and thereby increase its fatigue life. A specialized high temperature damping material, in the form of vitreous enamel, was utilized to work effectively over the operational temperature range of the exhaust extension. The application of this high temperature damping material to the engine exhaust extension has significantly reduced the vibrational amplitudes at resonance and thereby increased component service life.

79-53

New Structural Damping Technique for Vibration Control

B.M. Patel, G.E. Warnaka, and D.J. Mead

Lord Kinematics, Erie, PA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 39-52 (Sept 1978) 12 figs, 7 refs

Key Words: Material damping, Vibration control

A new structural damping configuration is presented which makes efficient use of damping materials by subjecting them to both shear and extensional deformations. The configuration consists, in one form, of a series of rows of vertically oriented platelets with damping material sandwiched between them. Adjacent rows of platelets may overlap each other to enhance the deformation of the damping material. A theoretical analysis of the configuration is summarized. The new structural damping configuration is shown to apply to very rigid structures where it can control flexural vibrations and sound radiation with low added weight. The new structural damping design optimization study is made and a numerical example is included.

79-54

Computerized Processing and Empirical Representation of Viscoelastic Material Property Data and Preliminary Constrained Layer Damping Treatment Design

L.C. Rogers and A.D. Nashif

Air Force Flight Dynamics Lab., Wright Patterson AFB, OH, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 23-37 (Sept 1978) 15 figs, 4 tables, 5 refs

Key Words: Material damping, Viscoelastic damping, Computer-aided techniques

Technology advancements in the state-of-the-art of processing and representing modulus and loss factor data as a function of temperature and frequency are presented; further, a new method for performing preliminary constrained layer damping treatment design covering the complete range of interest of practical engineering parameters is outlined.

79-55

A Reduced-Temperature Nomogram for Characterization of Damping Material Behavior

D.I.G. Jones

Air Force Materials Lab., Wright Patterson AFB, OH 45433, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 13-22 (Sept 1978) 14 figs, 6 tables

Key Words: Material damping, Mechanical properties, Nomographs

An adaptation of the well known "reduced-frequency" concept for linear damping materials is made, so as to produce a "reduced-temperature" nomogram. This simple nomogram has the advantage of allowing one to directly read off the complex modulus properties of damping materials at any given temperature and frequency, without the need for intermediate calculations.

79-56

Specification of Damping Material Performance

D.I.G. Jones and J.P. Henderson

Air Force Materials Lab., Wright Patterson AFB, OH 45433, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 1-11 (Sept 1978) 8 figs, 2 tables, 1 ref

Key Words: Material damping, Nomographs, Resonance bar technique, Dynamic modulus of elasticity

In this paper a simple reduced-temperature nomogram is applied to developing a specification for controlling damping material performance, and the resonant beam test technique is discussed as a possible standard method for measuring complex dynamic moduli of damping materials.

79-57

The Influence of Geometry on Linear Damping

M.E. McIntyre and J. Woodhouse

Dept. of Appl. Mathematics and Theoretical Physics, Univ. of Cambridge, Acustica, 39 (4), pp 209-224 (Mar 1978) 7 figs, 17 refs

Key Words: Internal damping, Geometric effects, Plates, Shells, Musical instruments

Internal damping of vibration modes of bodies such as plates and shells generally depends on mode shape, boundary conditions and geometry. This dependence is explored systematically using linear continuum mechanics, exploiting the differences between different complex moduli which are frequently ignored, particularly in isotropic materials. Detailed results are given for isotropic plates, of constant and slightly varying thickness, under various boundary conditions. One prediction of the theory is tested experimentally.

ELASTIC

79-58

Wave Propagation in Strongly Anisotropic Elastic Materials

W.A. Green

Dept. of Theoretical Mech., Univ. of Nottingham, UK, Arch. Mech. Stosowanej, 30 (3), pp 297-307 (1978) 8 refs

Key Words: Wave propagation, Elastic media

In this paper the nature of wave propagation in a strongly transversely isotropic elastic material is examined. For the case considered the extensional modulus in the direction of the axis of transverse isotropy is much greater than that in any direction at right angles to this axis. The results for both the idealized inextensible and transversely isotropic materials are derived. The speeds of propagation and associated discontinuity vectors are obtained. Some generalizations to non-linear elastic materials are suggested.

FLUID

(Also see Nos. 39, 114, 115, 158)

79-59

Fluidelastic Vibration of Heat Exchanger Tube Arrays

H.J. Connors, Jr.

Westinghouse Res. Labs., Pittsburgh, PA, J. Mech. Des., Trans. ASME, 100 (2), pp 347-353 (Apr 1978) 10 figs, 12 refs

Key Words: Tubes, Heat exchangers, Whirling, Fluid-induced excitation

A basic fluidelastic excitation mechanism, of a type reported in an earlier paper, causes large whirling vibrations of tubes in model arrays when the flow velocity exceeds a critical value. Threshold instability constants are given that were obtained from wind tunnel and water tunnel tests on multi-row tube arrays in uniform cross flow. Test results are discussed that demonstrate the effects of spanwise variations in flow velocity on fluidelastic whirling for both straight tubes and U-tubes. Design methods are provided for predicting the onset of fluidelastic whirling of heat exchanger tubes on multiple supports when spanwise variations in the cross flow exist.

79-60

On Some Aspects of Unsteady Aerodynamics and Vortex Induced Oscillations of Elliptic Cylinders at Subcritical Reynolds Number

V.J. Modi and L. Ieong

Dept. of Mech. Engrg., Univ. of British Columbia, Vancouver, B.C., Canada, J. Mech. Des., Trans. ASME, 100 (2), pp 354-362 (Apr 1978) 12 figs, 25 refs

Key Words: Cylinders, Vortex-induced vibration, Fluid-induced excitation

The paper presents results of an extensive test program aimed at better understanding of unsteady aerodynamics and vortex induced oscillations of a family of two dimensional elliptic cylinders in the Reynolds number range of $3 \times 10^4 - 10^5$. In the beginning, results on Strouhal number variation with cylinder eccentricity and angle of attack are presented which can be used to predict critical resonant velocity once the structural properties are identified. This is followed by the data on the fluctuating pressure at the surface of the cylinders which suggest their three dimensional character and significant dependence on the Reynolds number.

79-61

Aerodynamic Force and Moment on Oscillating Airfoils in Cascade

H. Atassi and T.J. Akai

Univ. of Notre Dame, Notre Dame, IN, ASME Paper No. 78-GT-181

Key Words: Airfoils, Aerodynamic loads

A systematic theory is developed for airfoils in cascade oscillating about their mean position with constant interblade phase angle in a uniform incompressible flow. The theory fully accounts for the effect of angle of attack of the mean flow, the airfoils' thickness and camber, and the cascade solidity and stagger. The formulation leads to two singular integral equations in the complex plane which are solved numerically by collocation.

79-62

Acoustic Radiation Due to a Fluid Loading Discontinuity on an Infinite Membrane

M. Pierucci

General Dynamics Electric Boat Div., Groton, CT 06340, J. Acoust. Soc. Amer., 64 (1), pp 223-231 (July 1978) 11 figs, 5 refs

Key Words: Membranes, Interaction: structure-fluid, Elastic waves

Eigen-mode radiation is determined for an infinite membrane

with a discontinuous fluid loading condition. The upper half of the membrane is exposed to a heavy fluid which accounts for a fluid-structure interaction. The lower half of the membrane is exposed to very light fluid which imposes no fluid loading on the structure. A very soft compliant layer is attached to half of the membrane surface. The compliant layer lessens the local coupling between the fluid and the structure, thus creating the fluid loading discontinuity. The effect of this fluid loading discontinuity upon the radiated farfield is evaluated.

79-63
A Numerical Nonlinear Method of Sloshing in Tanks with Two-Dimensional Flow
O.M. Faltinsen
Div. of Ship Hydrodynamics, Norwegian Inst. of Tech., Trondheim, Norway, J. Ship Res., 22 (3), pp 193-202 (Sept 1978) 13 figs, 8 refs

Key Words: Tanks (containers), Sloshing, Damping

A numerical method for the study of sloshing in tanks with two-dimensional flow is presented. The solution satisfies the exact nonlinear free-surface conditions. To avoid difficulties with transients, artificial damping is introduced. Comparison with a linear analytical solution, derived in this publication, shows that the numerical method gives reasonable results. Comparison with an approximate nonlinear analytical method, derived earlier by the author, indicates that the artificial damping leads to difficulties in special cases.

SOIL

(See Nos. 13, 81)

VISCOELASTIC

79-64
Vibration of a Viscoelastic Bar in Consideration of the Correlation Between Random Parameters
N. Nakagawa, R. Kawai, T. Iwatsubo, and K. Funahashi
Faculty of Engrg., Kobe Univ., Rokko, Nada, Kobe 657, Japan, Bull. JSME, 21 (157), pp 1089-1094 (July 1978) 5 figs, 2 tables, 7 refs

Key Words: Bars, Viscoelastic properties, Random parameters, Spring constants, Damping coefficients

The longitudinal vibration of a viscoelastic bar which has random properties with respect to both the stiffness and the viscoelasticity is considered. The viscoelastic bar is substituted by an n-degrees-of-freedom linear chain and the method to obtain the standard deviations of displacements etc. is given by developing Caravani's method. The correlation of the spring rate and the damping coefficient is also taken into consideration. The standard deviations are calculated to five-degrees-of-freedom in the numerical example.

EXPERIMENTATION

DIAGNOSTICS

79-65
Design a Mobile Machinery Analysis Laboratory
U. Sela
Exxon Co., U.S.A., Benicia, CA., Hydrocarbon Processing, 57 (8), pp 115-118 (Aug 1978) 6 figs, 2 refs

Key Words: Diagnostic techniques, Test facilities

A mobile machinery analysis laboratory has repeatedly proven its usefulness by helping to avoid unnecessary shutdowns and by accurately predicting internal equipment damage (thus minimizing repair downtime). The mobile laboratory is used for the troubleshooting of all types and sizes of rotating machinery and other miscellaneous equipment. The laboratory contains vibration sensors, associated electronics, recording, analysis and data display devices. This instrumentation package is housed in a step-van type truck which, in effect, is a mobile measurement laboratory. The van is also used as a data reduction, analysis and storage center.

79-66
Random Fatigue Damage Approach to Machinery Maintenance
T.S. Sankar, G.D. Xistris, and G.L. Ostiguy
Concordia Univ., Montreal, Quebec, Canada, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 3, pp 103-114 (Sept 1978) 7 figs, 2 tables, 16 refs

Key Words: Diagnostic techniques, Machinery, Mechanical elements, Random excitation

Machinery vibration are employed to obtain an estimate of the stresses in critical mechanical elements under opera-

ting conditions. The amount of fatigue damage incurred as a result of these stresses is computed using a linear damage accumulation law and expressions are developed for the expected value of the damage sustained over a specific time period. The behavior of these statistical parameters with operating time and with various system fatigue properties is discussed. The calculated damage provides a reliable indication of the remaining trouble-free life and can be employed in the maintenance field to monitor the performance of industrial machinery.

79-67

Can Acoustic Emission Detect the Initiation of Fatigue Cracks: Application to High-Strength Light Alloys Used in Aeronautics

C. Bathias, B. Brinet, and G. Sertour

NASA, Washington, D.C., Rept. No. NASA-TM-75306, 10 pp (June 1978)

N78-26493

Key Words: Nondestructive tests, Acoustic techniques, Fatigue (materials)

Acoustic emission was used for the detection of fatigue cracking in a number of high-strength light alloys used in aeronautical structures. Among the features studied were: the influence of emission frequency, the effect of surface oxidation, and the influence of grains. It was concluded that acoustic emission is an effective nondestructive technique for evaluating the initiation of fatigue cracking in such materials.

79-68

AIDAPS Program

K.R. Bartholic, J.D. Chang, F.C. Elder, W.J. Harris, and J.L. Lau

Airesearch Mfg. Co. of California, Torrance, CA, Rept. No. USAAVRADCOM-TR-78-5, 144 pp (Oct 24, 1977)

AD-A054 972/5GA

Key Words: Diagnostic instrumentation, Computer-aided techniques, Aircraft

This report summarizes the technical accomplishments on the Automatic Inspection, Diagnostic and Prognostic System (AIDAPS) Program during the period of 27 June 1973 to 30 Nov 1976. AIDAPS was intended for use in Army Aircraft and was intended to be used to reduce maintenance cost and improve flight safety by continuous inflight monitoring of aircraft subsystems.

79-69

SPADE Sensor Location and Attachment

T.C. Mayer, H.W. Sutphin, and J.T. Harrington

Parks College of Saint Louis Univ., Cahokia, IL, Rept. No. USAAVRADCOM-TR-78-7, 21 pp (Jan 27, 1978)

AD-A054 907/1GA

Key Words: Shock pulse method, Diagnostic instrumentation, Helicopters

This report optimizes sensor locations for the shock pulse vibration technique, investigates the shock emission profile difference between using an IFD multi-model transducer using an epoxy mounting technique vs a B and K accelerometer using a collar and damp technique and finally the recommendation of candidate bearings for shock pulse monitoring on the UH-1H, AH-1G, OH-58C, and the CH-47.

EQUIPMENT

79-70

MIL-STD-781C Random Reliability Testing Performed by Using Acoustic Coupling

S.M. Landre

Electronic System Div., Harris Corp., Melbourne, FL, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 49-56 (Sept 1978) 17 figs, 3 refs

Key Words: Random vibration, Shakers

This paper describes an approach for performing random vibration during reliability testing by using an acoustic coupled shaker system. The new Revision C to MIL-STD-781 is requiring either random or sine vibration during temperature cycling, depending on the equipment specification. The requirement to subject some test items to random vibration instead of sine vibration creates demands for inexpensive replacement equipment capable of performing the new tests.

79-71

Stability and Frequency Response of Hydro-Mechanical Shakers in Vibration Rigs

S. Sankar

Dept. of Mech. Engrg., Concordia Univ., Montreal, Canada, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 33-47 (Sept 1978) 12 figs, 2 tables

Key Words: Shakers

A hydro-mechanical shaker is an effective alternate to an electro-hydraulic shaker for providing low frequency, large displacement and force. This paper presents an analytical study on the stability and frequency response of hydro-mechanical shakers used for generating vibrational signals to drive a vibration rig. The analytical expression for stability are derived based on linearized flow characteristic equations and taking into account the effect of fluid inertance and resistance in the connecting pipes.

79-72

Broad-Band Mechanical Vibration Amplifier

R.T. Fandrich

Electronic Systems Div., Harris Corp., Melbourne, FL, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 25-31 (Sept 1978) 9 figs, 3 refs

Key Words: Test equipment and instrumentation, Amplifiers, Shakers, Vibration testing

A test requirement to expose miniature electronic components to high vibration levels encouraged this investigation of a mechanical vibration amplifier. Various testing requirements are imposed on components and many of these requirements are too high to be met using standard laboratory vibration shakers. The solution described in this paper utilizes a mechanical vibration amplifier which increases the available shaker output at all frequencies, simultaneously.

FACILITIES

(Also see No. 65)

79-73

A Method of Assessing the Precision of Reverberation-Room Sound-Absorption Measurements

S.M. Brown and K.D. Steckler

Res. and Dev. Center, Armstrong Cork Co., Lancaster, PA 17604, Acustica, 40 (1), pp 1-14 (May 1978) 4 tables, 9 refs

Key Words: Reverberation chambers, Acoustic absorption

An efficient and economical method of assessing the full precision of sound-absorption coefficients derived from a minimal number of reverberation-room decay repetitions is described. Expressions are derived for the relevant statistical parameters, and a scheme is presented for checking the statistical assumptions employed. An examination of measurements performed in our laboratory shows that these assumptions usually hold quite well. These methods employ the "theory of error propagation" and are applicable to a wide variety of situations, both in and beyond acoustics.

79-74

Effects on Precision of a Reverberant Absorption Coefficient of a Plane Absorber due to Anisotropy of Sound Energy Flow in a Reverberation Room

Y. Makita and K. Fujiwara

Kyushu Inst. of Design, Fukuoka, Japan, Acustica, 39 (5), pp 331-346 (Apr 1978) 6 figs, 1 table, 7 refs

Key Words: Reverberation chambers, Acoustic absorption, Test facilities

Effects of anisotropic sound energy flow in a reverberation room on the precision of a measurement in the room of a reverberant absorption coefficient of a plane absorber are studied theoretically. The upper and the lower limits of a region are given wherein the random incident absorption coefficient of the plane absorber is estimated from two factors: the measured reverberant absorption coefficient and the normalized angular distribution of sound energy flow in the sound field near the absorber.

INSTRUMENTATION

(Also see No. 68)

79-75

The Reciprocity Calibration of Vibration Standards Over an Extended Frequency Range

R.R. Bouche

Bouche Laboratories, Sun Valley, CA., Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 105-111 (Sept 1978) 5 figs, 1 table, 10 refs

Key Words: Accelerometers, Calibrating

Reciprocity calibrations are performed at various frequencies up to 10,000 Hz using an air-bearing shaker with a built-in primary standard accelerometer. The shaker is used for sensitivity and frequency response calibrations on other accelerometers and velocity pickups in the range of 10 Hz to 10,000 Hz and up to 50,000 Hz for resonance frequency calibrations.

79-76

Angular Vibration Measurement Techniques

P.W. Whaley and M.W. Obal

Air Force Flight Dynamics Lab., Wright Patterson AFB, OH 45433, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 83-93 (Sept 1978) 12 figs, 11 refs

Key Words: Accelerometers, Vibration meters, Aircraft, Airborne equipment response, Angular vibration

The angular and linear vibratory response of aircraft structures affects airborne electro-optical packages. In order to design these systems with acceptable pointing accuracies and sufficient subsystem mirror alignments, knowledge of the angular responses of aircraft structures is important. Thus, it is necessary to be able to measure angular vibrations of aircraft structures in order to describe optical package disturbances. Six angular vibration sensors were encountered in a literature survey and are evaluated in light of the above requirements. In addition, experience with differential angular vibration measurement using conventional accelerometers is presented and evaluated.

79-77

Frequency Response and Directional Characteristics of Sound Level Meters in the Presence of an Operator

K. Brinkmann and K. Obermayr
Physikalisch-Technische Bundesanstalt, Braunschweig, Federal Republic of Germany, Noise Control Engr., 11 (1), pp 32-39 (July/Aug 1978) 11 figs, 6 refs

Key Words: *Sound level meters, Error analysis*

Frequency response and directional characteristics of sound level meters can be considerably distorted by the presence of an operator in the sound field, especially when tonal noise is being measured. The magnitude of the errors depends on features of the device itself and on the exact location of the operator and his build. Detailed experimental data on these effects are presented, including various sound level meter and measuring conditions.

TECHNIQUES

(Also see Nos. 32, 41, 50, 113)

79-78

Modal Confidence Factor in Vibration Testing

S.R. Ibrahim
Dept. of Mech. Engrg. and Mechanics, Old Dominion Univ., Norfolk, VA., Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 1, pp 65-75 (Sept 1978) 3 figs, 4 tables

Key Words: Modal tests, Modal analysis, Vibration tests, Testing techniques

The "Modal Confidence Factor", "MCF", is a number calculated for every identified mode for a structure under test. The theory of the MCF is based on the correlation that exists between the modal deflection at a certain station and the modal deflection at the same station delayed in time. The theory and application of the MCF is illustrated by two experiments. The first experiment deals with simulated responses from a two degree of freedom system with 20%, 40%, and 100% noise added. The second experiment was run on a generalized payload model.

79-79

On the Distribution of Shaker Forces in Multiple-Shaker Modal Testing

W.L. Hallauer, Jr. and J.F. Stafford
Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 1, pp 49-63 (Sept 1978) 14 figs, 2 tables, 20 refs

Key Words: Modal tests, Modal analysis, Vibration tests, Testing techniques

The method proposed by Asher for structural dynamic modal testing by multiple-shaker sinusoidal excitation is reviewed, and its theory and application are discussed in detail. Numerical results from simulated modal testing on mathematical structural models are presented to illustrate the strengths and weaknesses of the method. The characteristics of these models include damping which couples the normal modes and closely spaced modes. Numerical techniques required for implementation of the method are described. A procedure is suggested for replacing actual mechanical tuning with calculations employing transfer function data.

79-80

Force Apportioning for Modal Vibration Testing Using Incomplete Excitation

G. Morosow and R.S. Ayre
Martin Marietta Corp., Denver, CO, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 1, pp 39-48 (Sept 1978) 6 figs, 2 tables, 9 refs

Key Words: Modal tests, Modal analysis, Vibration tests, Testing techniques

A technique is presented for determining the shaker forces necessary to isolate a mode during a modal vibration test. The approach requires no prior knowledge of the model and is particularly usable for structures with high modal density.

79-81

High Frequency Ground Vibration Measurement

H. Nolle
Monash Univ., Clayton, Victoria, Australia, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 95-103 (Sept 1978) 6 figs, 1 table, 8 refs

Key Words: Measurement techniques, Ground vibration

Recently interest has focused on ground transmitted vibration and noise from sources related to human activity such as mining and tunneling work, as well as traffic and industrial plant operations. The disturbance thus generated contains low and high frequency Fourier components, and accurate measurement of the vibration requires recording of the signal free from harmonic distortion in the frequency range of interest. This paper reviews the basic requirements for vibration transducer-to-ground coupling to ensure linear measuring system response. Results are presented of field tests of a range of different designs for ground attachments, and recommendations are made for procedures of ground attachment installation in different type soils and rock formations.

79-82
Conservatism in Random Vibration Analysis and Testing
T.L. Paez
Appl. Mech. Div., Sandia Laboratories, Albuquerque, NM 87115, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 57-70 (Sept 1978) 5 figs, 3 tables, 2 refs

Key Words: Vibration tests, Random vibration, Testing techniques

This paper reports conservatism in random vibration testing. It shows that some common spectral density estimators have an approximately normal sampling probability distribution. Based on this fact, the study proposes some measures of confidence in specified test levels. The study describes a technique for finding the probability that a test is more severe than the field environment from which it was derived. A mean square structural response criterion is used.

79-83
Which Vibration Test
R.M. Kolodziej
Air Power Div., Joy Mfg. Co., Buffalo, NY, Mach. Des., 50 (18), p 113 (Aug 10, 1978)

Key Words: Testing techniques, Vibration tests

Three techniques commonly used in vibration testing: impact, swept sine, and random (white noise) are described. The decision on which technique, or combination, to use depends on part geometry, available time, required accuracy, and required information – natural frequencies, damping factors, phase shift, stiffness, mode shape, etc. A table is provided for a quick reference for the best method to use based on these variables.

COMPONENTS

BEAMS, STRINGS, RODS, BARS

(Also see Nos. 114, 138, 197)

79-84
Shock Analysis of Tubular Viscoplastic Beams (Final Report, 1 Jan - 31 Dec 1976)
S.G. Gatchel and V.H. Neubert
Dept. of Engrg., Science and Mech., Pennsylvania State Univ., University Park, PA, Rept. No. AD-A053185; FR-2, 114 pp (July 1977)
N78-26495

Key Words: Beams, Cantilever beams, Viscoplastic properties, Computer programs

An analytical method is outlined, and a related computer program Viscoplastic Beam Analysis (VPBA) is discussed, for prediction of response of a viscoplastic cantilever beam to ground shock. Some beams, which could be built using standard piping, are designed and analyzed using inputs typical of those on the floating shock barge.

79-85
Dynamics of Neutrally Buoyant Inflated Viscoelastic Tapered Cantilevers Used in Underwater Applications
V.J. Modi and D.T. Poon
Dept. of Mech. Engrg., Univ. of British Columbia, Vancouver, British Columbia, Canada, J. Mech. Des., Trans. ASME, 100 (2), pp 337-346 (Apr 1978) 10 figs, 1 table, 23 refs

Key Words: Cantilever beams, Underwater structures, Inflatable structures, Dynamic response

The paper investigates statics and dynamics of neutrally buoyant inflated viscoelastic tapered cantilevers used as

structural members in underwater platforms. Results of a detailed experimental program are also presented to substantiate validity of the analytical model.

79-86

The Large Amplitude Vibration of Hinged Beams

G. Prathap and T.K. Varadan
Indian Inst. of Tech., Madras-600036, India, Computers Struc., 9 (2), pp 219-222 (Aug 1978) 3 figs, 2 tables, 12 refs

Key Words: Beams, Free vibration

The large amplitude free vibrations of a simply-supported beam with ends kept a constant distance apart is studied using the actual nonlinear equilibrium equations (i.e. specification of loads in terms of the deformed coordinates of the beam) and the exact nonlinear expression for curvature in addition to the nonlinearity arising from the axial force. A variable separable assumption, together with certain assumptions as to the behavior of the time function defines an eigenvalue characteristic of the vibration. A numerically exact successive integration and iterative technique establishes the dependence of this quantity on the amplitude of vibrations. The hardening effect of nonlinearity is then interpreted in terms of the variation of this quantity with the amplitude of vibration. This new criteria to define nonlinearity, is compared with several existing in the literature. The present analysis allows the separation of the effects of stretching and large deflection equations on the nonlinear behavior and the conclusion can be made, based on numerical evidence, that the predominant nonlinearity is due to stretching. The axial force at any station in the beam and the bending stress can also be computed in a numerically exact sense, at the point of maximum amplitude.

79-87

Transverse Compressional Damping in the Vibratory Response of Elastic-Viscoelastic-Elastic Beams

B.E. Douglas and J.C.S. Yang
David W. Taylor Naval Ship Res. and Dev. Center, Annapolis, MD, AIAA J., 16 (9), pp 925-930 (Sept 1978) 6 figs, 9 refs

Key Words: Beams, Laminates, Viscoelastic properties, Flexural vibration, Viscoelastic damping

The effects of transverse compressional damping in the vibratory response of three-layer elastic-viscoelastic-elastic beams are considered both analytically and experimentally in a mechanical impedance format. The relative importance of this type of damping is assessed through comparison with the shear damping mechanism inherent in the composite using the Mead and Markus model.

79-88

Instabilities of Tubular Beams Simultaneously Subjected to Internal and External Axial Flows

M.J. Hannoyer and M.P. Paidoussis
Dept. of Mech. Engrg., McGill Univ., Montreal, Quebec, Canada, J. Mech. Des., Trans. ASME, 100 (2), pp 328-336 (Apr 1978) 7 figs, 18 refs

Key Words: Beams, Tubes, Fluid-filled containers, Fluid-induced excitation

This paper examines the dynamics and stability of cylindrical tubular beams conveying fluid and simultaneously subjected to axial external flow. In deriving the equation of small motions, inviscid hydrodynamic forces are obtained by slender-body theory, modified to account for the boundary-layer thickness of the external flow; internal dissipation and gravity effects are also taken into account. Solutions are obtained by means of a method similar to Galerkin's, with the eigenfunctions approximated by Fourier series. Calculations are presented for tubular beams either clamped at both ends or cantilevered. It is shown that for sufficiently high flow velocities, either internal or external, the system is subject to divergence and/or flutter.

79-89

Vibration Damping of Tapered Unconstrained Beams

D.K. Rao
Dept. of Mech. Engrg., Indian Inst. of Tech., Kharagpur, India, Acustica, 39 (4), pp 264-269 (Mar 1978) 8 figs, 2 tables, 4 refs

Key Words: Beams, Variable cross section, Cantilever beams, Material damping

The effects of boundary conditions and non-uniform distribution of the damping material over a beam on its composite loss factor are investigated in the present paper. This study indicates that, for a cantilever beam, the conventional method of uniformly applying the damping material over the entire length of the beam may not be the best way of attaining good damping. An alternative tapered distribution of the same amount of damping material, which is thickest at the clamped edge and thinnest at the free edge, can be 300 per cent more effective in damping the flexural vibration.

79-90

Use of Dynamic Influence Coefficients in Forced Vibration Problems with the Aid of Fast Fourier Transform

G.V. Narayanan and D.E. Beskos
Dept. of Civil and Mineral Engrg., Univ. of Minnesota, Minneapolis, MN 55455, Computers Struc., 9 (2),

pp 145-150 (Aug 1978) 6 figs, 16 refs

Key Words: Beams, Flexural vibration, Forced vibration, Stiffness coefficients, Fast Fourier transform

The use and importance of dynamic stiffness influence coefficients in flexural forced vibrations of structures composed of beams are described. The dynamic forces can be either harmonic or general transient forces. The dynamic influence coefficients are defined in the Fourier transform plane, are computed there and are given in Table form for a uniform free-free beam. The dynamic problem formulated in terms of these coefficients is reduced to a static form. The dynamic response is obtained, in general, by a matrix inversion in the Fourier transform plane and a numerical inversion, based on the Cooley-Tukey algorithm, of the transformed solution. Structural examples of forced vibrations of a simple beam and a rigid frame illustrate the use of dynamic coefficients and demonstrate their advantages over other known methods in accuracy, simplicity of formulation and speed of computation.

79-91

A Finite Element for the Vibration Analysis of Timoshenko Beams

D.J. Dawe

Dept. of Civil Engrg., The Univ. of Birmingham, Birmingham B15 2TT, UK, J. Sound Vib., 60 (1), pp 11-20 (Sept 8, 1978) 5 figs, 1 table, 25 refs

Key Words: Beams, Finite element techniques, Timoshenko theory, Rotatory inertia effects, Transverse shear deformation effects, Flexural vibration

A Timoshenko beam finite element is presented which has three nodes and two degrees of freedom per node, namely the values of the lateral deflection and the cross-sectional rotation. The element properties are based on a coupled displacement field; the lateral deflection is interpolated as a quintic polynomial function and the cross-sectional rotation is linked to the deflection by specifying satisfaction of the governing differential equation of moment equilibrium in the absence of the rotary inertia term. Numerical results confirm that this procedure does not preclude convergence to true Timoshenko theory solutions since rotary inertia is included in lumped form at element ends.

79-92

Dynamic Stability of Timoshenko Beams Resting on an Elastic Foundation

B.A.H. Abbas and J. Thomas

Dept. of Mech. Engrg., Univ. of Surrey, Guildford, GU2 5XH, UK, J. Sound Vib., 60 (1), pp 33-44 (Sept 8, 1978) 12 figs, 1 table, 7 refs

Key Words: Beams, Elastic foundations, Timoshenko theory, Rotatory inertia effects, Transverse shear deformation effects, Periodic excitation

A finite element model is developed for the stability analysis of a Timoshenko beam resting on an elastic foundation and subjected to periodic axial loads. The effect of an elastic foundation on the natural frequencies and static buckling loads of hinged-hinged and fixed-free Timoshenko beams is investigated. The regions of dynamic instability are determined for different values of the elastic foundation constant. As the elastic foundation constant increases the regions of dynamic instability are shifted away from the vertical axis and the width of these regions is decreased, thus making the beam less sensitive to periodic forces.

79-93

Dynamic Coefficient of an Elastically Supported, Pre-Stressed Beam

S. Chonan

Sendai, Japan, Ing. Arch., 47 (3), pp 187-196 (1978)

Key Words: Beams, Elastic foundations, Axial excitation, Transverse shear deformation effects, Rotatory inertia effects

An analysis is made of the problem of vibrations of a beam with an axial force resting on elastic foundation, when the beam is uniform and of finite length and is subjected to an impulsive load. The solution is presented within the framework of a beam theory which includes the effects of shear deformation and rotary inertia. An example is provided where the dynamic coefficient for the bending moment is calculated.

79-94

Vibration of the Uniform Spinning Cable with Tip Mass

O.L. Vance and C.R. Katholi

Univ. of Alabama in Birmingham, Birmingham, AL 35294, J. Acoust. Soc. Amer., 64 (3), pp 838-844 (Sept 1978) 5 figs, 2 tables, 8 refs

Key Words: Cables, Free vibration

This paper presents analyses of both in-plane and out-of-plane free vibrations of a uniform cable with tip mass attached to a disk turning at constant rate about a fixed axis. Included in the analyses is the development of small-argument asymptotic approximations for the Legendre functions of the first and second kinds.

79-95
The Effect of Kinematical Non-Linearities on the Vibration Frequencies of a Damped String
J.C. Arya
Dept. of Mech. Engrg., Simon Fraser Univ., Burnaby, British Columbia V5A 1S6, Canada, Acta. Mech., 29, pp 159-167 (1978) 1 fig, 8 refs

Key Words: Strings, Flexural vibration, Damped structures

The effect of kinematical non-linearities on the transverse vibration modes of a damped stretched string is investigated using the asymptotic method of Krylov, Bogoliubov and Mitropolskii. It is shown that for times which are small compared with the decay time, the natural frequencies are increased by a term which is proportional to the square of the amplitude of vibration. The nature of this term is investigated in detail for a particular set of boundary conditions at the ends of the string.

79-96
Subharmonic Vibrations of Order 1/3 in Stretched Strings
C.R. Raghunandan and G.V. Anand
Acoustics Lab., Dept. of Electrical Comm. Engrg., Indian Inst. of Science, Bangalore 560 012, India, J. Acoust. Soc. Amer., 64 (1), pp 232-239 (July 1978) 8 figs, 15 refs

Key Words: Strings, Subharmonic oscillations

Subharmonic vibrations of order 1/3 in stretched strings driven by a single-mode planar simple harmonic force are investigated. It is shown that both planar and nonplanar subharmonic resonances can occur. Subharmonic vibrations are possible only if the amplitude of the force exceeds a certain critical value which depends upon the magnitude of the damping coefficient. The stability of the solution is analyzed, and it is shown that the region of stable nonplanar vibrations is wider than that of stable planar vibrations.

79-97
Buckling of Euler's Rod in the Presence of Ergodic Random Damping
H.H.E. Leipholz
Dept. of Civil Engrg., Solid Mech. Div., Univ. of Waterloo, Waterloo, Ontario, Canada, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 3, pp 49-52 (Sept 1978) 1 fig, 4 refs

Key Words: Rods, Damping, Buckling

This paper is concerned with the buckling of Euler's rod in the presence of ergodic random damping. For a small mean value of viscous damping, superposed by an ergodic random damping fluctuation, it is shown that for a sufficiently small expected value of the fluctuation's magnitude, almost certain asymptotic stability can be guaranteed. Moreover, if the expected value does not exceed a certain fraction of the damping's mean value, the critical value of the load for deterministic damping remains the stability limit despite of the randomly superposed damping fluctuation.

BEARINGS

79-98
Dynamic Characteristics of Gas-Lubricated Externally Pressurized Porous Bearings with Journal Rotation: I
N.S. Rao and B.C. Majumdar
Dept. of Mech. Engrg., Indian Inst. of Tech., Kharagpur, India, Wear, 50, pp 59-70 (Sept 1978) 6 figs, 2 tables, 9 refs

Key Words: Gas bearings, Bearings, Damping coefficients, Stiffness coefficients, Rotor-bearing systems

The dynamic stiffness and damping coefficients of an externally pressurized porous bearing with journal rotation have been calculated theoretically by assuming one-dimensional flow through the porous wall. A periodic disturbance (displacement) is imposed on the journal around its concentric position and the dynamic pressure distribution is determined by small perturbations of the modified Reynolds equation. Non-dimensional stiffness and damping coefficients for various design conditions are calculated numerically using a digital computer and presented in the form of design charts and tables.

BLADES

79-99
Vibrations of a Compressor Blade with Slip at the Root
D.I.G. Jones and A. Muszyńska
Air Force Materials Lab., Wright Patterson AFB, OH, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 53-61 (Sept 1978) 15 figs, 1 table

Key Words: Compressor blades, Turbine blades

A simple analytical model is developed to represent the vibrational behavior of a jet engine compressor blade in its

fundamental mode, allowing for slip at the root. The analysis is compared with experimental data and is shown to accurately modelize the important phenomena involved. Implications for design of compressor and turbine blades to optimize slip damping levels are briefly discussed.

79-100

An Investigation of the Aerodynamic Noise Generation Mechanism of Circular Saw Blades

S. Stewart
Noise Control Services, Inc., P.O. Box 5670, Greensboro, NC 27403, Noise Control Engr., 11 (1), pp 5-11 (July/Aug 1978) 10 figs, 18 refs

Key Words: Saws, Blades, Tools, Noise generation

Aerodynamic disturbances, created near the periphery of rotating saw blades, are the dominant noise sources for most circular sawing machines while in the idling condition. In this article, an acoustic model based on simple dipole source theory is developed which identifies the importance of tip speed and source strength in the noise generation process.

COLUMNS

79-101

Concise Buckling, Vibration and Static Analysis of Structures Which Include Stayed Columns

F.W. Williams and W.P. Howson
Dept. of Civil Engrg. and Building Tech., Univ. of Wales Inst. of Science and Tech., King Edward VII Ave., Cardiff CF1 3NU, Wales, Intl. J. Mech. Sci., 20 (8), pp 513-520 (1978) 3 figs, 10 refs

Key Words: *Columns, Buckling, Vibration response*

The substitute columns previously used to give exact elastic critical loads of individual stayed columns also give their exact member equations, which represent them in stiffness matrix analyses, very economically. A typical example indicates that the substitute columns give the member equations with 6% of the effort involved in a standard sub-structure analysis of the original column, or 2% if the column is symmetric about its center.

CYLINDERS

79-102

Vibrations in Fluid-Saturated Porous Elastic Cylinders

M.D. Thajuddin
Dept. of Mathematics, Regional Engrg. College, Warangal-506 004, India, Rev. Roumaine Sci. Tech. Mecanique, 23 (3), pp 371-379 (1978) 11 refs

Key Words: Cylinders, Flexural vibration

Taking general displacement components of vibratory motion, the problems of flexural extensional and screw vibrations in fluid-saturated poroelastic cylinders are studied. Phase velocity and group velocity are presented in non-dimensional form for small values of dimensionless wavelength.

DUCTS

79-103

A Method for Calculating the Sound Attenuation in a Silencer, Consisting of Finite Sections of Bulk Reacting Lining in a Cylindrical Duct with Mean Flow

O. Brander and B. Nilsson
Inst. of Theoretical Physics, Chalmers Univ. of Tech., Goteborg, Sweden, Rept. No. CTH-ITP-TMF-77-1, 88 pp (Sept 30, 1977)
N78-26882

Key Words: Ducts, Acoustic linings

A general method is presented for taking into account the reflection, transmission, and propagation of all relevant modes in a silencer, consisting of finite sections of bulk-reacting lining in a cylindrical duct with gas flow. The general problem is thus reduced to the study of two standard problems. The first is the well known, but not yet completely worked, throw problem of an infinite duct with bulk-reacting lining and flow. Some numerical results are presented which stress the importance of an often overlooked phenomenon in this connection - the so called amplifying modes. The second problem concerns the reflection and transmission properties of a junction between two different sections of the duct. This problem is solved with integral equation methods from the theory of electromagnetic wave guides.

79-104

Boundary Conditions for Mode-Matching Analyses of Coupled Acoustic Fields in Ducts

R.J. Beckemeyer and D.T. Sawdy

Boeing Wichita Co., Wichita, KS, AIAA J., 16 (9), pp 912-918 (Sept 1978) 9 figs, 25 refs

Key Words: Ducts, Sound propagation, Modal superposition method

The mode-matching method is used to analyze sound propagation in ducts modeled by a series of segments. Successful application of the method depends on adequately specifying and imposing the boundary conditions used to match the acoustic fields on the junctions between segments. Although the boundary conditions may be derived by straightforward physical or mathematical arguments, the method by which they must be imposed in order to produce a well-posed numerical problem is not always clear. To illustrate this point, difficulties encountered when attempting to impose the matching conditions for a duct with a partial transverse baffle are discussed; several methods of approach are considered. Two of them were used to analyze a complicated duct-cavity system. Samples of the numerical results obtained are given.

79-105

Multimodal Far-Field Acoustic Radiation Pattern Using Mode Cutoff Ratio

E.J. Rice

Lewis Res. Center, NASA, Cleveland, OH, AIAA J., 16 (9), pp 906-911 (Sept 1978) 9 figs, 15 refs

Key Words: Ducts, Sound waves, Modal analysis

The far-field sound radiation theory for a circular duct was studied for both single-mode and multimodal inputs. The investigation was intended to develop a method to determine the acoustic power produced by turbofans as a function of mode cutoff ratio. This information is essential for the design of acoustic suppressors in engine ducts. With reasonable simplifying assumptions, the single-mode radiation pattern was shown to be reducible to a function of mode cutoff ratio only (modal indices removed). With modal cutoff ratio as the dominant variable, multimodal radiation patterns can be reduced to a simple explicit expression. Radiation patterns for cases other than equal modal power are presented using the approximate radiation equation. An approximate expression for the duct termination losses as a function of cutoff ratio also is included.

79-106

Duct Effects on the Heave Stability of Plenum Air Cushions

M.J. Hinchey and P.A. Sullivan

Inst. for Aerospace Studies, Univ. of Toronto, Toronto, Canada, J. Sound Vib., 60 (1), pp 87-99 (Sept 8, 1978) 8 figs, 19 refs

Key Words: Ducts, Ground effect machines, Stability

Linear heave stability boundaries for a fan-duct-plenum air cushion suspension system are presented. These were obtained by using a quasi-static pressure-flow relationship for the fan, a finite element discretization for one dimensional unsteady duct flow, and a lumped capacitance model for the plenum. Some results obtained from a non-linear analysis, in which the method of characteristics was used for the duct flow, suggest that the linear approach should be adequate for practical stability calculations. Comparisons with lumped parameter models indicate that here the duct effect is associated primarily with the inertance of the air in the duct. It is also shown that for some operating conditions the duct-plenum system behaves as an Helmholtz resonator. Good agreement is obtained with an earlier transmission line analysis based on the wave equation.

GEARS

79-107

Rotational Vibration with Backlash: Part 1

C.C. Wang

FMC Corp., Santa Clara, CA, J. Mech. Des., Trans. ASME, 100 (2), pp 363-373 (Apr 1978) 18 figs, 5 refs

Key Words: Gears, Torsional vibration, Mathematical models, Experimental data

This paper considers the problem of dynamic tooth loads on lightly loaded precision class gears running at high speed. It provides theoretical and experimental explanations of the surprising fact that lightly loaded gears may suffer from both pitting and tooth breakage, while the same gear, heavily loaded, is immune from such damage. In the theoretical part, two idealized mathematical models – a two-mass system and a three-mass system – are analyzed. Both models provide for consideration of time-varying backlash (backlash is a function of gear angular position) as well as impact and displacement excitations.

LINKAGES

79-108

Performance Classifications Help You Zero in on the Right Flexible Coupling

R.C. Beercheck

Mach. Des., 50 (19), pp 100-105 (Aug 24, 1978) 4 figs

Key Words: Flexible couplings

Flexible couplings are grouped into four basic performance categories: heavy duty, high speed, light duty, and specialty. In each category applications of representative couplings are indicated. These classifications, based on load, speed, and damping characteristics, help narrow the search quickly to the most likely candidates.

MECHANICAL

79-109
Torque-Limiting Devices
R.A. Dvorak
Helland Research & Engineering, Inc., Minnetonka, MN, Power Transm. Des., 20 (9), pp 41-43 (Sept 1978) 8 figs

Key Words: Torque limiting devices

A general design criteria of mechanically actuated torque limiters for efficient means of equipment protection is described.

MEMBRANES, FILMS, AND WEBS

79-110
Acceleration Waves in Elastic Membranes
J.J. Pop
Ph.D. Thesis, Rice Univ., 191 pp (1978)
UM 7814794

Key Words: Membranes, Wave propagation

This work is devoted to a study of acceleration waves in isotropic, inhomogeneous, smooth, non-linear, elastic membranes. The wave is modeled as a curve, moving on a fixed surface in space, carrying with it a finite discontinuity in the acceleration field. The method employed in the analysis is the analogue of the singular surface theory used in continuum mechanics.

PANELS

79-111
Dynamic Response of a Structural Panel by Bolotin's Method
C.E.S. Ueng and R.C. Nickels, Jr.
School of Engrg. Science and Mech., Georgia Inst. of Tech., Atlanta, GA 30332, Intl. J. Solids Struc., 14 (7), pp 571-578 (1978) 6 figs, 4 tables, 5 refs

Key Words: Rectangular panels, Panels, Box type structures, Bolotin method, Asymptotic approximation

Bolotin's asymptotic method is adopted for the investigation of dynamic response of a rectangular structural panel with elastic edge constraints resembling a box structure. Experimental determination on the frequency response is also included for comparison purpose. The method is proven to be extremely versatile in solving a broad class of the aforementioned problems.

PIPES AND TUBES

79-112
Stability and Vibrations of Thick-Walled Tubes Subjected to Finite Twist and External Pressure
A. Ertepinar
Dept. of Engrg. Sciences, Middle East Tech. Univ., Ankara, Turkey, Intl. J. Solids Struc., 14, pp 715-722 (1978) 4 figs, 17 refs

Key Words: Tubes, Dynamic stability

Stability and small vibrations of long, thick-walled, circular cylindrical tubes subjected to finite twist and external pressure are investigated using the theory of finite elastic deformations in conjunction with the theory of small deformations superposed on large elastic deformations. The material of the tube is assumed to be isotropic, elastic, homogeneous and incompressible. A numerical scheme is adopted to solve the system of partial differential equations and the associated boundary conditions governing the problem. The effect of finite twist on the frequencies and the loss of stability due to uniform external pressure is displayed by various curves relating the frequencies to initial radial deformation parameter.

79-113
Time Domain Identification of Standing Wave Parameters in Gas Piping Systems
S.R. Ibrahim and E.C. Mikulcik
Dept. of Mech. Engrg., and Mechanics, Old Dominion Univ., Norfolk, VA 23508, J. Sound Vib., 60 (1), pp 21-31 (Sept 8, 1978) 2 figs, 2 tables, 10 refs

Key Words: Piping systems, Natural frequencies, Measurement techniques, Time-dependent parameters

A method for experimentally determining the natural fre-

quencies and modal pressures of an air or gas piping system is presented. Such information is of interest in installations where pressure pulsations caused by pumps or compressors are of importance. In the method a time domain based technique is used which was originally developed as an alternative to frequency response methods for determining the vibration parameters (natural frequencies, modes, damping factors) of structures, to avoid difficulties often encountered in interpreting complex and non-conclusive frequency response data such as arises from systems having numerous modes, some of which may be highly damped or closely spaced in frequency. In this application, a straight steel pipe with a sound source at one end and closed at the other end was used. The free pressure response following a rapidly swept sinewave input was recorded, digitized and then used in a computational procedure based on a lumped parameter representation of the system. The natural frequencies and the corresponding modal pressure ratios at the two stations, thus obtained, are compared with the theoretical values and values obtained from a simple frequency sweep. It is important to mention here that although in the experiment reported here an external frequency sweep excitation was used, the technique works as well with free decay response after a system shut-off, impulse response or random responses from normal system operation.

79-114

The Effect of Fluid Viscosity on Coupled Tube/Fluid Vibrations

T.T. Yeh and S.S. Chen
Components Technology Div., Argonne National Lab., Argonne, IL 60439, J. Sound Vib., 59 (3), pp 453-467 (Aug 8, 1978) 9 figs, 1 table, 6 refs

Key Words: Beams, Tubes, Fluid-induced excitation

This paper presents an analytical study of coupled vibration of two coaxial tubes separated by an incompressible viscous fluid. Tube vibrations are in beam modes and fluid motion is assumed to take place in a plane perpendicular to the axis of the tubes. First, the fluid forces acting on the tubes associated with small tube displacements are obtained in closed form based on the linearized two-dimensional Navier-Stokes equation. Then free and forced vibrations of the coupled tube/fluid system are analyzed. Finally, numerical results for free vibrations of simply supported tubes are presented for several cases to illustrate the effect of various system parameters.

PLATES AND SHELLS

(Also see Nos. 20, 57, 133, 161, 197)

79-115

Experimental and Theoretical Dynamic Analysis of Carbon-Graphite Composite Shells

A. Harari and B.E. Sandman
Naval Underwater Systems Center, Newport, RI 02840, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 3, pp 33-37 (Sept 1978) 1 fig, 3 tables, 3 refs

Key Words: Shells, Composite structures, Honeycomb structures, Submerged structures, Underwater structures, Natural frequencies, Mode shapes, Fluid-induced excitation

A comparison between experimental and theoretical models of a carbon-graphite/honeycomb composite shell vibrating in air and submerged in water is presented. Mode shapes and resonant frequencies are identified according to theory and experiment both for in-air and in-water vibration. Excellent agreement is exemplified.

79-116

Free Vibrations of Circular Cylinders with Longitudinal, Interior Partitions

M.R. Peterson and D.E. Boyd
Garrett Air Research Mfg. Co., Phoenix, AZ, J. Sound Vib., 60 (1), pp 45-62 (Sept 8, 1978) 10 figs, 5 tables, 25 refs

Key Words: Cylindrical shells, Free vibration

A method for the analysis of the free vibrations of a circular cylindrical shell with a longitudinal, interior plate is developed. This method is based on the extended Rayleigh-Ritz technique. Separate displacement functions are assumed for the shell and plate. Constraint equations are used to enforce displacement compatibility between the plate and shell. The importance of including the in-plane degrees of freedom of the plate in the analysis is investigated. Studies are made to determine the effects on the system frequencies and modes of rigid and hinged joints between the plate and shell and the location of the plate.

79-117

Dynamic Deformations and Stresses in a Cantilever Cylindrical Shell Under Impulsive Loads

S. Ujihashi, H. Wakai, H. Matsumoto, and I. Nakahara
Faculty of Engrg., Tokyo Inst. of Tech., Ookayama, Meguro-ku, Tokyo, Japan, Bull. JSME, 21 (158) pp 1208-1215 (Aug 1978) 12 figs, 11 refs

Key Words: Cylindrical shells, Cantilever beams, Flügge's shell theory, Wind-induced excitation, Seismic excitation

In this paper the dynamic displacements and stresses of a cantilever circular cylindrical shell, which is suddenly loaded

by shearing forces on its free edge, are analyzed within the framework of Flügge's shell theory.

79-118

Torsional Vibrations of Nonhomogeneous Cylinders and Cylindrical Shells

B.M. Singh and R.S. Dhaliwal
Dept. of Mechanics and Statistics, Univ. of Calgary, Alberta, Canada T2N 1N4, Bull. Acad. Polon Sci., Ser. Sci. Tech., 26 (3), pp 157-163 (1978) 5 refs

Key Words: Circular cylinders, Cylindrical shells, Torsional vibration

An analysis is developed for the torsional oscillations of circular cylinders and cylindrical shells in which the density and rigidity vary in both radial (r) as well as axial (z) directions. The shear wave velocity is assumed to be constant or a function of the radial distance but independent of z. The equation of motion is solved for some particular forms of the heterogeneity. Finally, the frequency equations are obtained for many different cases.

79-119

Dynamic Behaviour of Thin Cylindrical Shells Subjected to Transient Inner Pressures

S. Suzuki
Dept. of Aeronautical Engrg., Nagoya Univ., Chikusa-ku, Nagoya 464, Japan, Nucl. Engr. Des., 49 (3), pp 223-229 (Sept 1978) 4 figs, 11 refs

Key Words: Cylindrical shells, Transient excitation, Internal pressure, Laplace transformation

Stress analysis is carried out for horizontal thin cylindrical shells subjected to transient inner pressures resulting from the closure of a terminal valve. The velocity of water at a valve is adjusted to become v_0e^{-bt}. The relationships between the dynamic hoop stresses acting on the neutral axis of the wall of a cylinder, the hydraulic pressures, the dimensions of a cylinder and time are obtained.

79-120

Wave Propagation in a Cylindrical Shell with Joint Discontinuity

A. Harari
Naval Underwater Systems Center, Newport, RI 02840, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 3, pp 53-61 (Sept 1978) 9 figs, 5 refs

Key Words: Cylindrical shells, Joints (junctions), Discontinuity-containing media, Wave propagation

The effects of joint discontinuity on wave propagation in a cylindrical shell are investigated in this paper. The joint discontinuity consists of an elastic interlayer at the joint and structural discontinuity of the joint. The transmitted and reflected efficiencies are found for several cases of interest.

79-121

Characterization of Torpedo Structural Modes and Resonant Frequencies

C.M. Curtis, R.H. Messier, B.E. Sandman, and R. Brown
Naval Underwater Systems Center, Newport, RI 02840, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 1, pp 119-136 (Sept 1978) 24 figs, 1 table

Key Words: Torpedoes, Transient response, Shock response, Resonant frequencies, Mode shapes, Shells, Mathematical models, Finite element technique

A typical torpedo can be described as an assembly of complex structures contained within a ribbed shell of variable shape and thickness. For this reason, the generality embodied in the finite element method lends itself well to the construction of an analytical model of a torpedo structure. In the present study a torpedo shell is modeled with plate and beam elements which internal components are represented as discrete masses on spring mounts. Analytical procedures and test data were used to formulate the various internal component models.

79-122

Vibration Analysis of Hyperbolic Cooling Towers Due to Earthquake Excitations

H. Kondo
Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan, Bull. JSME, 21 (157), pp 1095-1102 (July 1978) 10 figs, 9 refs

Key Words: Cooling towers, Hyperbolic parabolic shells, Reinforced concrete, Seismic response

The hyperboloidal shells of revolution supported on columns have been used effectively as natural draft cooling towers of reinforced concrete. The purpose of this paper is to analyze the dynamic response of hyperbolic cooling towers to earthquake excitations. Taking the propagating velocity of earthquake excitations into account, the author shows that hyperbolic cooling towers oscillate not only in beam vibration modes but also in such higher vibration modes as ovalization of their cross sections.

79-123

NASTRAN And SAP IV Applications on the Seismic Response of Column-Supported Cooling Towers

C.S. Gran and T.Y. Yang

School of Aeronautical and Astronautical Engrg., Purdue Univ., West Lafayette, IN 47907, Computers Struc., 8 (6), pp 761-768 (June 1978) 10 figs, 15 refs

Sponsored by the U.S. National Science Foundation

Key Words: Cooling towers, Shells, Seismic response, Computer programs, NASTRAN (computer program), SAP (computer program)

Hyperboloidal reinforced-concrete shells are modeled using orthotropic quadrilateral flat plate finite elements. The supporting columns and top ring-beam are modeled by beam finite elements. Natural frequencies and corresponding mode shapes are found for several different tower configurations. Results for fixed-base shells are in close agreement with those determined using alternate methods of analysis.

79-124

In-Plane Vibration of Plates by Continuous Mass Matrix Method

B. Ovunc

Dept. of Civil Engrg., Univ. of Southwestern Louisiana, P.O. Box 4-0172, Lafayette, LA 70504, Computers Struc., 8 (6), pp 723-731 (June 1978) 14 figs, 3 tables, 24 refs

Key Words: Plates, Vibration response, Matrix methods, Finite element technique

The continuous mass matrix method derived for frameworks is extended to the analysis of in-plane vibration of plates. A continuous mass distribution which is the same as the actual mass distribution of the plate is considered over each rectangular finite element. Taking into account that the rigid body movement produces inertial forces in dynamic analysis for a rectangular plate element eight independent conditions are provided to satisfy eight independent freedoms. Each condition is obtained from an independent displacement distribution satisfying the equations of motion at any point of the element and not only at the nodes of the rectangle. The dynamic element stiffness matrix thus obtained is a function of the natural circular frequency. The limit of the dynamic element stiffness matrix when the value of the natural circular frequency tends to zero is the static, stress compatible element stiffness matrix. The analysis of plates under forcing forces is performed by modal analysis after the natural circular frequencies and the corresponding modal shapes have been obtained from the free vibrations, for all the forcing forces are assumed to be function of the same time variation.

79-125

Natural Frequencies of a Four Point-Supported Rectangular Plate Using the Rayleigh-Ritz Method

J. Kerstens

Space Dept., Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost, Rept. No. FOK-RV-77-38, 38 pp (Mar 1977)

N78-25450

Key Words: Plates, Solar cells, Natural frequencies, Fundamental frequency, Rayleigh-Ritz method

In the design of solar panels the first natural frequency must be as high as possible for a plate supported by four hold-down points. The energy method is used to obtain the fundamental frequency of this plate. This fundamental frequency is computed using the Rayleigh-Ritz method.

79-126

Finite Strip Models for Vibration of Mindlin Plates

D.J. Dawe

Dept. of Civil Engrg., The Univ. of Birmingham, Birmingham B15 2TT, UK, J. Sound Vib., 59 (3), pp 441-452 (Aug 8, 1978) 5 figs, 6 tables, 18 refs

Key Words: Rectangular plates, Flexural vibration, Finite strip method, Mindlin theory, Transverse shear deformation effects, Rotatory inertia effects

Four finite strip models are developed for the flexural vibration analysis of rectangular plates based on Mindlin theory which takes account of transverse shear deformation and of rotary inertia. The strips are simply supported at their ends and differ one from another in the order of interpolation employed to represent the variation of each of the plate deflection and the two rotations across the strip. The four models are based in turn on quadratic, cubic, quartic and quintic interpolation. Numerical results are presented of applications of the strip models to the calculation of the natural frequencies of both thin and moderately thick plates. The influence that the assumed value of the shear coefficient has on natural frequencies is considered for two particular moderately thick plates.

79-127

Use of Asymptotic Solutions from a Modified Bolotin Method for Obtaining Natural Frequencies of Clamped Rectangular Orthotropic Plates

K. Vijayakumar and G.K. Ramaiah

Dept. of Aeronautical Engrg., Indian Inst. of Science, Bangalore 560012, India, J. Sound Vib., 59 (3),

pp 335-347 (Aug 8, 1978) 1 fig, 3 tables, 25 refs

Key Words: Rectangular plates, Natural frequencies, Flexural vibration, Bolotin method, Asymptotic approximation, Rayleigh-Ritz method

Solutions of the problem of flexural vibration of clamped rectangular orthotropic plates are initially obtained by a modified Bolotin's asymptotic method and these solutions are then used as admissible functions in the Rayleigh-Ritz method. Estimates of frequencies obtained by the modified Bolotin, Rayleigh and Rayleigh-Ritz methods are presented. Accuracies of these estimates are discussed in detail.

79-128

Transverse Vibration of a Rectangular Plate Elastically Restrained Against Rotation Along Three Edges and Free on the Fourth Edge

P.A.A. Laura and R. Grossi
Inst. of Applied Mechanics, 8111 Base Naval Puerto Belgrano, Argentina, J. Sound Vib., 59 (3), pp 355-368 (Aug 8, 1978) 9 figs, 5 tables, 9 refs

Key Words: Rectangular plates, Flexural vibration, Ritz method

A literature search has shown that the title problem has received no treatment. In the present study the problem is solved by the Ritz method with deflection functions which are simple polynomials. Frequency coefficients for the fundamental mode and two other higher natural dynamic states are presented.

79-129

Free Vibration Analysis of Rectangular Plates with Inelastic Lateral Support on the Diagonals

D.J. Gorman
Dept. of Mech. Engrg., Univ. of Ottawa, Ottawa, Canada, J. Acoust. Soc. Amer., 64 (3), pp 823-826 (Sept 1978) 2 figs, 1 table, 10 refs

Key Words: Rectangular plates, Free vibration

An analytical solution is obtained for the problem of the free vibration of a rectangular plate with simple support at the edges and inelastic lateral support along one diagonal. The solution, of the double sine series type introduced by Navier, can readily be extended to plates with similar support on both diagonals and different kinds of edge support.

79-130

A Semi-Analytic Solution for Free Vibration of Rectangular Plates

M. Mukhopadhyay
Dept. of Naval Architecture, Indian Inst. of Tech., Kharagpur- 721 302, India, J. Sound Vib., 60 (1), pp 71-85 (Sept 8, 1978) 6 figs, 9 tables, 11 refs

Key Words: Rectangular plates, Free vibration

By substituting the basic function satisfying boundary conditions along two opposite edges in one direction of the plate and then using a suitable transformation, the free vibration equation of the shape function of the plate is reduced to an ordinary differential equation. The resulting equation is expressed in finite difference form. The problem is thus transformed into an eigenvlaue problem which on solution yields the natural frequencies of free vibration of plates. Examples have been presented for a variety of plates having different boundary conditions and having constant and variable thickness. Excellent accuracy has been obtained.

79-131

Upper and Lower Bounds to the Natural Frequencies of Vibration of Clamped Rectangular Orthotropic Plates

R.D. Marangoni, L.M. Cook, and N. Basavanhally
Dept. of Mech. Engrg., Univ. of Pittsburgh, Pittsburgh, PA 15261, Intl. J. Solids Struc., 14, pp 611-623 (1978) 11 figs, 4 tables, 16 refs

Key Words: Natural frequencies, Rectangular plates, Orthotropism

The Rayleigh-Ritz technique, using clamped beam eigen functions, has been employed to determine the upper bounds for the eigenvalues for a clamped orthotropic plate. The decomposition technique after Bazely and Fox has been used to estimate the lower bounds for the first few natural frequencies. The estimates for the upper bounds have been evaluated for all modes by not imposing any restriction on the symmetry conditions. Variations of the first two natural frequencies for various rigidity and aspect ratios which can be of some use to the designers are presented. Also the upper and lower bounds for the first few natural frequencies are tabulated. Comparison of the results for special cases with other reported data have been made whenever such results are available.

79-132

Asymmetric Vibration and Stability of Circular Plates

G.C. Pardoen

Univ. of California, Irvine, CA 92717, Computers Struc., 9 (1), pp 89-95 (1978) 3 figs, 2 tables, 15 refs

Key Words: Rings, Circular plates, Vibration response, Finite element technique

The asymmetric vibration and stability of circular and annular plates using the finite element method is discussed. The plate bending model consists of one-dimensional circular and annular ring segments using a Fourier series approach to model the problem asymmetries. Using displacement functions which are the exact solutions of the static plate bending equation, the stiffness coefficients corresponding to the 1st and nth harmonics are used in closed form. Several numerical examples are presented to demonstrate the efficiency and accuracy of the finite element model with that of classical methods.

RINGS

(Also see No. 132)

79-133

Dynamic Stability of Annular Plates Under Periodic Radial Loads

J. Tani and T. Nakamura

Inst. of High Speed Mechanics, Tohoku Univ., Sendai, Japan, J. Acoust. Soc. Amer., 64 (3), pp 827-831 (Sept 1978) 8 figs, 13 refs

Key Words: Rings, Plates, Periodic excitation

The dynamic stability of clamped annular plates of which both the edges are subjected to the same periodic radial loads is studied theoretically. The Galerkin procedure is used to reduce the problem to that for a finite degree-of-freedom system, the stability boundaries of which are determined by utilizing Hsu's result for coupled Hill's equations. For three typical annular plates, the instability regions of both principal and combination resonances are determined for a wide range of exciting frequencies with the effect of static compressive forces taken into consideration.

SPRINGS

79-134

Response of a Helical Spring Considering Hysteretic and Viscous Damping

P.F. Mlakar and R.E. Walker

U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 63-74 (Sept 1978) 8 figs, 1 table, 8 refs

Key Words: Helical springs, Hysteretic damping, Viscous damping, Resonant response, Mathematical models

An analytical model of a helical spring is developed which includes distributed mass, viscous damping, and hysteretic damping. The limiting effects of both types of damping on the resonant response are discussed. The model is seen to compare reasonably with existing experimental data.

STRUCTURAL

79-135

Vibration of Structural Members Caused by Nonstationary Excitation (Bauwerksschwingung infolge nichtstationaerer Erregung)

P. Klippel

Technische Univ., Berlin, West Germany, Rept. No. ILR-Ber-24, 102 pp (1977)

(In German)

N78-25460

Key Words: Structural members, Parametric response

Numerical parameterization methods are developed for predicting responses of structures and structural members to dynamic loads. Application of oscillatory velocities for estimating dynamic loads acting on vibrating structures establishes a correlation between extreme bending stress and extreme oscillation velocity, regardless whether stationary/periodic- or transient-excitations are applied.

79-136

Dynamic Response of Structures in Frequency Domain

A.M.S.A. Abdelrahman

Ph.D. Thesis, Polytechnic Inst. of New York, 83 pp (1978)

UM 7816740

Key Words: Frequency domain, Wind induced excitation, Structural response, Seismic excitation

The primary purpose of this investigation is the evaluation of the dynamic response of structures using frequency domain method. The present dissertation contains two parts. Part I deals with the subcritical excitation and dynamic response of structures in frequency domain. Part II deals with the along-wind gust effect on elevated structures.

79-137

Analytical and Numerical Investigation of Structural Response of Compliant Wall Materials. Part 1

R. Balasubramanian

Old Dominion Univ., Norfolk, VA, Rept. No. NASA-CR-2999, 98 pp (May 1978)

N78-25458

Key Words: Walls, Nonlinear response

Surface motion of compliant walls in drag reduction experiments was analyzed. Critical comparison was made between the dynamic motion of the structure and the postulated mechanism of drag reduction. The spectrum of surface motion indicated that membranes over deep cavities respond at low frequencies and large wavelengths. Computer programs developed for these analyses are documented.

79-138

Earthquake Resistant Structural Walls - Tests of Coupling Beams

C.B. Barney, K.N. Shiu, B.G. Rabbat, and A.E. Fiorato

Construction Technology Labs., Portland Cement Assn., Skokie, IL., Rept. No. NSF/RA-760844, 142 pp (Oct 29, 1976)

PB-281 733/6GA

Key Words: Earthquake resistant structures, Walls, Beams, Reinforced concrete, Dynamic tests

Design criteria for reinforced concrete structural walls used as lateral bracing in earthquake resistant buildings are being developed. Tests are conducted to investigate the behavior of reinforced concrete coupling beams under reversing loads. This report covers test details and preliminary results for the first six coupling beam tests. Four specimens with diagonal reinforcement and two with no diagonal reinforcement were tested.

79-139

Structural Walls in Earthquake Resistant Structures: Analytical Investigation - Dynamic Analysis of Isolated Structural Walls - Parts A and B

M. Fintel, A.T. Derecho, S.K. Ghosh, M. Iqbal, and G.N. Freskakis

Construction Technology Labs., Portland Cement Assn., Skokie, IL., Rept. No. NSF/RA-760849, 285 pp (Oct 1976)

PB-281 623/9GA

Key Words: Earthquake resistant structures, Walls, Computer aided techniques

The objectives of the first part of this analysis are to evaluate the relative influence of various structural and ground motion parameters on the dynamic response to shear forces and deformations in critical regions of structural walls; to determine estimates of critical force and deformation requirements in hinging regions of structural walls corresponding to different combinations of earthquake intensity and the significant structural parameters; and to correlate data on critical dynamic response with data from laboratory tests of isolated walls under reversing loads to arrive at recommendations on design force levels.

TIRES

79-140

Static and Dynamic Analysis of Cast and Cast Carcass Tires

J.R. Hampton

Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH, Rept. No. AFFDL-TR-78-42, 94 pp (Mar 1978)

AD-A054 941/0GA

Key Words: Aircraft tires, Dynamic tests

The AFFDL/FEM initiated a program to establish the potential of cast tires for application to Air Force aircraft. This program involved the analysis of seventy-five (75) cast 6.00-6 Type III aircraft tires which were rotationally cast/molded from a thermoplastic polyester elastomer material (Hytrel). These tires have a continuous toroidal construction and do not have textile reinforcement or bead bundles. The first of a two phase program involved static and dynamic analysis of off-the-shelf light industrial vehicle cast tires which had a rated maximum loading of 415 lbs and rated maximum speed of 10 mph. The second phase of this in-house test program resulted in a 6.00-6 size cast tire which satisfactorily passed 89 laboratory dynamometer qualification taxi takeoff cycles.

SYSTEMS

ABSORBER

79-141

Cylinders: Softening the Blow

B.L. Rich

Cylinder Div., Parker Hannifin Corp., Des Plaines, IL, Mach. Des., 50 (12), pp 66-69 (May 25, 1978)

Key Words: Energy absorption

Four types of commercially available cylinder cushions for absorbing impacts caused by speeding pistons, are described. Straight-spear cushions are the most common, but stepped-spear and tapered-spear cushions are also widely used. Piccolo cushions have excellent deceleration characteristics, but because of their high cost, they are usually custom-designed units. Optimum terminal velocities of the cylinder and the selection of proper cushion is discussed.

79-142

Damping High-Pressure Low-Flow Energy Instantaneously

M.I. Korytko

Erie Press Systems, An EFCO Company, Erie, PA, Hydraulics and Pneumatics, 31 (4), pp 55-57 (Apr 1978) 5 figs

Key Words: Hydraulic presses, Energy dissipation

A hydraulic blanking press is described which dissipates the energy of 1000 tons of force at 3000 psi in less than 0.1 seconds, by means of catching cylinders built into the lower platten of the press. The cylinders stop the ram automatically the moment the punch breaks through the steel plate, preventing an overstroke of the punch. The low-flow shock waves thus generated are dissipated by specially designed non-mechanical shock dissipators immediately downstream of the catching cylinders.

79-143

Testing Piping Constraint Energy Absorbers for Reactor Containment Applications

R.C. Yaeger and R.C. Chou

Franklin Institute Res. Labs., Philadelphia, PA., Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 161-181 (Sept 1978) 15 figs, 1 ref

Key Words: Energy absorption, Piping systems, Nuclear reactor containment

An experimental program is described to test a design concept for durable low cost energy absorbers to be used as piping constraints in reactor containment structures.

79-144

Multi-Variable Optimization for Vibration Isolation of Road Vehicles

E. Esmailzadeh

Dept. of Mech. Engrg., Arya Mehr Univ. of Tech., Tehran, Iran, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 85-96 (Sept 1978) 8 figs, 8 refs

Key Words: Shock absorbers, Interaction: vehicle-terrain, Vehicle response, Vibration control

The transmission of road-generated vibrations into a vehicle body is treated as a source-path-receiver problem. The suspension system acts as the path, and improved isolation can be achieved by having a single compliant bushing at the connecting point of the shock absorber to the body with none at the other end. A mathematical model is derived for such a system and an expression for the absolute displacement transmissibility of the body and that of the wheel is derived. An optimization procedure is applied in order to evaluate the optimum values of the non-dimensional variables involved.

ACTIVE ISOLATION

79-145

A Modal Control Approach for Active Control of Multi-Story Structures

C.R. Martin

Ph.D. Thesis, State Univ. of New York at Buffalo, 84 pp (1978)

UM 7817063

Key Words: Multistory buildings, Wind induced excitation, Active damping

A problem of considerable current interest in structural engineering is the design of active control systems for civil engineering structures. While the problem of active structural control can be formulated based on classical optimal control theory, the combination of structural flexibility, dimension, and weight presents unique problems with respect to real-time controllability, control implementation, and economic feasibility. In this dissertation the concept of modal control is offered as a possible design technique for active structural control systems. The control objective is to affect direct changes of specific dynamic modes and stiffness of the system, and this is possible when the motion of the structural system consists mainly of a limited number of separable modes.

AIRCRAFT

(Also see Nos. 68, 76)

79-146

Community Noise Exposure Resulting from Aircraft Operations. Volume 5. Acoustic Data on Air Force Propeller Aircraft

J.D. Speakman, R.G. Powell, and R.A. Lee

Aerospace Medical Res. Lab., Wright-Patterson AFB, OH, Rept. No. AMRL-TR-73-110-VOL-5, 703 pp (Feb 1978)

AD-A055 079/8GA

Key Words: Aircraft noise, Noise measurement

This series of reports present the results of field test measurements to define the noise produced on the ground by military, fixed wing aircraft during controlled level flyovers and ground runups. For flight conditions, data are presented as a function of angle and distance to the aircraft. All of the data are normalized to standard acoustic reference conditions of 59 F temperature and 70% relative humidity.

79-147

Low Frequency Cabin Noise Reduction Based on the Intrinsic Structural Tuning Concept: The Theory and the Experimental Results. Phase 2

G. SenGupta

Boeing Commercial Airplane Co., Seattle, WA, Rept. No. NASA-CR-145262; D6-44283; D748-10113-3, 104 pp (Mar 1978)

N78-24900

Key Words: Aircraft, Noise reduction, Vibration tuning, Vibration damping

Low frequency cabin noise and sonically induced stresses in an airacraft fuselage may be reduced by intrinsic tuning of the various structural members such as the skin, stringers, and frames and then applying damping treatments on these members. The concept is also useful in identifying the key structural resonance mechanisms controlling the fuselage response to broadband random excitation and in developing suitable damping treatments for reducing the structural response in various frequency ranges. The mathematical proof of the concept and the results of some laboratory and field tests on a group of skin-stringer panels are described. In the so-called stiffness-controlled region, the noise transmission may actually be controlled by stiffener resonances, depending upon the relationship between the natural frequencies of the skin bay and the stiffeners. Therefore, cabin noise in the stiffness-controlled region may be effectively reduced by applying damping treatments on the stiffeners.

79-148

Calculation of Natural Frequencies and Mode Shapes of Mass Loaded Aircraft Structures

P.W. Whaley

Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 3, pp 13-20 (Sept 1978) 5 figs, 4 tables, 6 refs

Key Words: Aircraft, Natural frequencies, Mode shapes, Random vibration

Aircraft optical packages are forced by the local random vibration response characteristics of the airframe. Hence, the vibration characteristics must be known by the designer of optical packages. However, since the environment changes with the addition of the electro-optical system, it is necessary to predict the modified vibration environment, either by flight testing with mass simulations or conducting structural analysis. This paper poses the problem of loaded random vibration response estimation using Galerkin's method, a direct method, and a generalized coordinates approach.

79-149

Analytical and Experimental Fatigue Program for the Kfir Main and Nose Landing Gears

B. Abraham

Israel Aircraft Industries, Ltd., 7 pp (1977)

N78-25455

Key Words: Aircraft equipment, Landing gear, Fatigue life, Fatigue tests

The fatigue program began in the detail phase; next came the development of loading spectra used for analysis and test. A fatigue analysis was then performed for several suspected critical locations on both gears. A flight-by-flight test was performed on both landing gears with the aim of demonstrating four service lifetimes of operation. Design modifications were introduced, based on the results of these tests. Rational inspection and replacement intervals were established for the main and nose gear, some of which require monitoring of aircraft.

79-150

Effect of Loading-Program Modifications in Rotating-Bending Tests on Fatigue Damage Cumulation in Aircraft Material Specimens

A. Buch

Dept. of Aeronautical Engrg., Technion-Israel Inst. of Tech., Haifa, Israel, Rept. No. TAE-325, 42 pp (Nov 1977)

N78-25452

Key Words: Aircraft, Fatigue (materials), Fatigue tests

Multilevel rotating bending block tests were performed and the effect of stress peaks on the damage sum of notched aircraft material specimens was investigated. Test results were compared from the view points of the residual stress concept and of the nonlinear, stress dependent damage cumulation approach. The residual stress concept seems to be valid not only for nonsymmetrical axial loading but also for some rotating binding loading sequences, when stress peaks are acting. The nonlinear stress dependent damage cumulation approach is in good qualitative agreement with rotating bending test results, in the case where the role of residual stresses is negligible.

79-151

Light Airplane Crash Tests at Three Flight-Path Angles

C.B. Castle and E. Alfaro-Bou

Langley Res. Center, NASA, Langley Station, VA, Rept. No. NASA-TP-1210; L-12060, 69 pp (June 1978)

N78-26494

Key Words: Crash research (aircraft), Experimental data

Three similar twin engine general aviation airplane specimens were crash tested at Langley impact dynamics research facility at 27 m/sec and at flight-path angles of - 15 deg, - 30 deg, and - 45 deg. Other flight parameters were held constant. The test facility, instrumentation, test specimens, and test method are briefly described. Structural damage and accelerometer data for each of the three impact conditions are presented and discussed.

79-152

Mathematical Simulation for Crashworthy Aircraft Seat Design

D.H. Laananen

The Pennsylvania State Univ., University Park, PA, J. Aircraft, 15 (9), pp 567-573 (Sept 1978) 11 figs, 1 table, 15 refs

Key Words: Aircraft, Crash research (aircraft)

A three-dimensional mathematical model of an aircraft seat, occupant, and restraint system has been developed for use in the analysis of light aircraft crashworthiness. The occupant model consists of 12 rigid mass segments whose dimensions and inertial properties have been determined from studies of human body anthropometry and kinematics and from measurements of a production anthropomorphic test dummy. Because of the significant role played by the seat in overall system crashworthiness, a detailed finite-element model of the seat structure is included. The input data are structured so that any aircraft seat can be modeled by providing only nodal coordinates, element cross-sectional dimensions, and material properties. Plastic behavior is simulated by plastic hinges at the beam ends. Comparisons of model predictions with measured data for a dynamic test of an energy-absorbing seat are included.

79-153

Crashworthy Gunner Seat Testing Program

M.J. Reilly

Boeing Vertol Co., Philadelphia, PA, Rept. No. D210-11327-1, USARTL-TR-78-7, 155 pp (Mar 1977)

AD-A054 970/9GA

Key Words: Aircraft seats, Helicopter seats, Crashworthiness, Experimental results

A crashworthy gunner seat swivel concept developed under a previous contract was refined and detail drawings were made. Six seats were fabricated, four for static testing and two for dynamic testing. Modifications were made after the first four static tests. Additional static tests were successfully performed on two of the modified seats. A vertical drop test and a horizontal dynamic test were performed on the remaining two modified seats.

79-154

A Preliminary Investigation of Nomad Instrumentation Boom Vibration

P.A. Farrell and B. Quinn

Aeronautical Res. Labs., Melbourne, Australia, Rept. No. ARL/STRUC-TM-273, 11 pp (Feb 1978)

AD-A055 010/3GA

Key Words: Airborne equipment response, Booms (equipment), Vibration control

An investigation of the lower order modes of vibration of an instrumentation boom fitted to a Nomad aircraft was carried out and the results are presented. Recommendations for reducing the amplitude of boom vibration experienced at take-off are made.

79-155

Dynamics of the Longitudinal Motion of an Airplane with a Variable-Geometry Wing

Z. Dzygadlo and J. Maruszkiewicz

Warsaw, Poland, J. Tech. Phys., 19 (1), pp 125-137 (1978) 8 figs, 7 refs

Key Words: Aircraft, Longitudinal response, Aircraft wings

In order to investigate the peculiarities of modern aircrafts with variable-sweep wings, the dynamics of longitudinal perturbed motion of such an airplane is considered under the condition of varying sweep-back. The subject of the present study is the process of increasing and decreasing the wing sweep angle and the type of perturbations of flight parameters.

79-156

Captive Carriage Vibration of Air-to-Air Missiles on Fighter Aircraft

W.G. Frost, P.B. Tucker, and G.R. Waymon

F-15 System Program Office, Wright Field, Dayton, OH, J. Environ. Sci., 21 (5), pp 11-16 (Sept/Oct 1978) 14 figs, 12 refs

Key Words: Aircraft, Wing stores, Missiles, Vibration tests

Flight measurements obtained on F-15 fighter aircraft show that current missile vibration specifications do not adequately cover captive carriage. They include vibration caused by boundary layer noise, but not vibration induced by maneuvers. The latter occur at frequencies below approximately 200 Hertz. Vibration at these frequencies is much higher than specification test levels. It is therefore considered important that these vibration levels be incorporated in vibration qualification test specifications for future air-to-air missiles. Recommended vibration test levels and test procedures based on the F-15 flight measurements are provided.

79-157

The Vibration Response of the PHOENIX Missile in the F-14 Aircraft Captive-Flight Environment

M.E. Burke

Pacific Missile Test Center, Point Mugu, CA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 139-150 (Sept 1978) 14 figs, 2 tables, 4 refs

Key Words: Aircraft, Wing stores, Vibration response, Flight simulation

Vibration loads are an important cause of failures of air-launched missiles in the captive-flight environment. In order to reproduce these loads in testing it is first useful to understand the relationship between the induced vibration and the captive-flight parameters. This paper investigates the vibration response characteristics of the PHOENIX missile on the F-14 aircraft in the captive-flight environment. Variations in vibration response with flight condition, mounting configuration, direction, and location along the length of the missile are examined. The conclusions drawn in this report add conformation to previous captive-flight vibration studies in establishing general correlations between captive-flight parameters and captive-flight vibration.

BUILDING

(Also see Nos. 138, 139, 145, 164)

79-158

Effect of Turbulence on the Pressure Distribution and Vibration of Angular Bodies. Part I. Pressure Distribution on Model Buildings at Small Angles of Attack in Turbulent Flow. Part II. The Aeroelastic Vibration of the Square and H-Shaped Sections in Turbulent Cross Flows

J.A. Roberson and C.T. Crowe

Washington State Univ., Pullman, WA, Rept. No. TR/HY-1/78, 151 pp (Mar 31, 1978)
PB-282 439/9GA

Key Words: Buildings, Wind induced excitation, Turbulence

The study objectives were to determine the effects of free stream turbulence on the pressure distribution about rectangular building shapes and its effects on vibration of square and H-shaped sections.

79-159

Concorde Noise-Induced Building Vibrations: John F. Kennedy International Airport

W.H. Mayes, D.G. Stephens, R. DeLoach, J.M. Cawthorn, H.K. Holmes, R.B. Lewis, B.G. Holliday, D.W. Ward, and W.T. Miller

Langley Res. Center, NASA, Langley Station, VA, Rept. No. NASA-TM-78727; Rept-3, 47 pp (Apr 1978)
N78-26876

Key Words: Buildings, Acoustic excitation, Vibration response, Aircraft noise

Outdoor and indoor noise levels resulting from aircraft flyovers and certain nonaircraft events were recorded at eight homesites and a school along with the associated vibration levels in the walls, windows, and floors at these test sites. Limited subjective tests were conducted to examine the human detection and annoyance thresholds for building vibration and rattle caused by aircraft noise.

CONSTRUCTION

79-160
Road Construction Noise
D.J. Martin
Environment Div., Transport and Road Res. Lab., Noise Control Vib. Isolation, 9 (7), pp 278-282 (Aug/Sept 1978) 2 figs, 2 tables, 5 refs

Key Words: Construction equipment, Noise generation

Noise from construction and demolition works frequently gives cause for complaints by people living or working nearby. Noise legislation in the UK contained in the Control of Pollution Act has given powers to local authorities to control noise from these types of operation. These powers were designed to be effective in enabling local authorities to control any noise nuisance while avoiding hindrance or disruption of the works in question. In 1974 a research program was begun at the Transport and Road Research Laboratory (TRRL) to study noise from motorway, trunk road and principal road construction sites with the aim of producing a description of the noise climate around a site and a simple method of prediction. The aim of this research was to enable road planners to appreciate the effects of a proposed road construction on the noise environment and to take this into account at the design stage. The research would also assist local authorities in setting realistic noise limits and help site engineers and contractors to assess what measures would be needed to meet the limits. This paper summarizes some results of this research.

HELICOPTERS
(See Nos. 19, 183, 194)

HUMAN

79-161
On the Physical Background of the Point-Impedance Characterization of the Basilar Membrane in Cochlear Mechanics
M.A. Viergever
Dept. of Mathematics, Delft Univ. of Tech., The Netherlands, Acustica, 39 (5), pp 292-297 (Apr 1978) 2 figs, 24 refs

Key Words: Bioengineering, Mathematical models, Plates, Organs (biological)

A three-dimensional mathematical model of the cochlea is constructed. The basilar membrane is represented by a linear visco-elastic plate of variable width and thickness. It is shown that the point-impedance characterization of the basilar membrane is the analogue in one- and two-dimensional models of this visco-elastic plate representation.

ISOLATION

79-162
Design Synthesis of a Vehicle Suspension System Using Multi-Parameter Optimization
E. Esmailzadeh
Dept. of Mech. Engrg., Arya-Mehr Univ. of Tech., P.O. Box 3406, Tehran, Iran, Vehicle Syst. Dyn., 7 (2), pp 83-96 (Apr 1978) 7 figs, 17 refs

Key Words: Suspension systems (vehicles), Mathematical models, Gradient methods, Optimization

The transmission of road-generated vibrations into a vehicle body is treated as a source-path-receiver problem. The suspension system acts as the path, and improved isolation can be achieved by having a single compliant bushing at the connecting point of the shock absorber to the body with none at the other end. A mathematical model is derived for such a system which would enable detailed parameter investigation to be undertaken using the gradient method of optimization. An expression for the absolute displacement transmissibility of the body is derived and the optimization procedure is applied in order to evaluate the optimum values of the non-dimensional variables involved. This minimizes the maximum motion transmitted to the body from the road surface over a broad frequency range.

79-163
Experimental Results of an Earthquake Isolation System Using Natural Rubber Bearings
J.M. Eidinger and J.M. Kelly
Earthquake Engrg. Res. Center, California Univ., Berkeley, CA., Rept. No. UCB/EERC-78/03, 58 pp (Feb 1978)
PB-281 686/6GA

Key Words: Isolators, Elastomeric bearings, Earthquake resistant structures, Experimental data

This report describes the experimental results of a series of earthquake simulation tests on an earthquake isolation system based on natural rubber bearings. Three forms of isolation system were used. As the primary purpose of the test program was to examine the effect of damping in the

isolation system, the essential difference between the three forms was the level of the damping in the system. A large number of simulated earthquake motions were used in the tests including El Centro 1940, Taft 1950, Parkfield 1966 and Pacoima Dam 1971.

79-164

Floating Floors - How Effective Are They?

A.S. Saunders

Consultancy Group, Industrial Acoustics Co., Ltd., Noise Control Vib. Isolation, 9 (7), pp 272-276 (Aug/Sept 1978) 6 figs

Key Words: Isolators, Buildings, Floors, Floating bodies

In the construction of large buildings cost and space requirements often dictate placing a large, closely packed plant in a roof top plant area. This causes two problems: airborne sound transmission and vibration, which cannot be solved by means of standard anti-vibration measures, and structural isolation is required. The solution of the above problems, by means of wood or concrete floating floor, is described.

79-165

Isolation Mounts for the HEAO-B X-Ray Telescope

H.L. Hain and R. Miller

Lord Kinematics, Erie, PA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 2, pp 97-113 (Sept 1978) 17 figs, 1 table, 3 refs

Key Words: Isolators, Equipment mounts

This paper describes the orbiting HEAO-B X-ray Telescope experiment package and the isolation mounts which will be used to support and protect it. The design and testing phases of the isolation development program are fully described and data are presented.

79-166

Dynamic and Structural Analysis of Reusable Shipping and Storage Container for Encapsulated HARPOON Missile (RGM-84A)

C.P. Haber

Naval Weapons Handling Lab., Colts Neck, NJ, Rept. No. NWHL-7628, 56 pp (Apr 16, 1976)
AD-B011 686/3GA

Key Words: Missiles, Shipping containers, Isolators, Suspension systems (missiles)

A dynamic and structural analysis of a proposed reusable Shipping and Storage Container for the Encapsulated HARPOON Missile was made by the Naval Weapons Handling Laboratory as part of the design study for such container. The subject design incorporates a freebreathing fiberglass pod containing the encapsulated weapon. The pod and weapon are suspended from a truss-like outer structure by elastomeric mounts configured in a laterally focalized fashion. The analysis generates isolator parameters which attenuate the handling and transportation shock and vibration environment to safe levels for the weapon and verifies that the structural design concept can sustain the resulting loads.

MECHANICAL

(See No. 11)

PUMPS, TURBINES, FANS, COMPRESSORS

79-167

Gas Turbine Core Noise Source Isolation by Internal-to-Far-Field Correlations

B.N. Shivashankara

Boeing Commercial Airplane Co., Seattle, WA, J. Aircraft, 15 (9), pp 597-600 (Sept 1978) 8 figs, 3 refs

Key Words: Noise source identification, Electric power plants, Gas turbines

An auxiliary power unit was tested for exhaust noise in an anechoic chamber. Six internal and numerous near- and far-field microphones were employed. Extensive cross-correlation and coherence function analysis were performed.

79-168

A Program for Rating the Loudness of Consumer Fan Products

D.E. Clapp and C.E. Neelley

Texas A&M Univ., College Station, TX 77843, Noise Control Engr., 11 (1), pp 12-17 (July/Aug 1978) 2 figs, 1 table, 10 refs

Key Words: Fans, Noise measurement

The ongoing voluntary program established by the Home Ventilating Institute to rate their fan products for loudness is discussed. It is based on a one-third octave band sound power analysis conducted in a laboratory grade reverberation

room. Sound power measurements are converted to sound pressure levels and finally loudness in sones at a fixed distance from the source.

79-169

Acoustic Evaluation of a Novel Swept-Rotor Fan

J.G. Lucas, R.P. Woodward, and M.J. Mackinnon

Lewis Res. Center, NASA, Cleveland, OH, Rept. No. NASA-TM-78878; E-9612, 24 pp (1978)

Sponsored by AIAA

N78-24897

Key Words: Fans, Acoustic properties

Inlet noise and aerodynamic performance are presented for a high tip speed fan designed with rotor blade leading edge sweep that gives a subsonic component of inlet Mach number normal to the edge at all radii. The intent of the design was to minimize the generation of rotor leading edge shock waves thereby minimizing multiple pure tone noise. Sound power level and spectral comparisons are made with several high-speed fans of conventional design.

79-170

An Investigation into Steam Hammer Noise Using Scale Models and On-Line Computer Facilities

G.J. McNulty and J.C. Charman

Sheffield City Polytechnic, Noise Control Vib. Isolation, 9 (7), pp 285-291 (Aug/Sept 1978) 17 figs, 8 refs

Key Words: Steam hammer, Noise generation, Model testing, Scaling, Computer-aided techniques

This work details an investigation into the noise and vibration characteristics of a steam hammer using a 1/12th scaled engineering working model. The work was initiated with a view to locating the main sources of noise radiation, correlating the parameters of force against sound pressure and comparing this with previous work done on full scale hammers. This research project provided viable results which correlated accurately with the noise-producing characteristic of a full scale model.

RAIL

79-171

Track Structure Design Using Mathematical Models

W. So

Research and Test. Dept., Association of American Railroads, Chicago, IL, Rept. No. FRA/ORD-78/08, 60 pp (June 1978)

PB-282 357/3GA

Key Words: Railroad tracks, Mathematical models, Design techniques

The objective of the report is to demonstrate the use of mathematical track structure models in the development of design charts. The models have been developed in Task 1, Mathematical Modeling, of the Track Structures Research Program, Contract DOT-FR-30038. The charts should enable the optimal selection of track components and to evaluate the structural performance of existing track components in a given loading environment. The criterion for acceptable track design is that the strength of the track structure on a fatigue basis not be exceeded and the Miner's rule is used. The charts are based on arbitrarily chosen wheel-rail load magnitudes. For vertical wheel-rail loading, the loading configuration consists of eight wheel loads and corresponds to that of two adjacent trucks of two coupled 100 ton (90,720 kg) cars. For lateral wheel-rail loading, a single lateral load applied to the base of one rail is used.

79-172

High-Speed Ground Transport -- A Stochastic Model of Track Roughness and Misalignment

L.A. Balzer

The New South Wales Inst. of Tech., J. Mech. Engr. Sci., 20 (3), pp 143-148 (June 1978) 3 figs, 16 refs

Key Words: High speed transportation systems, Track roughness, Alignment, Mathematical models, Stochastic processes

One of the significant disturbances to a tracked hovercraft or any other high-speed ground transport vehicle is the roughness of the guideway surface together with misalignment of the guideway structure itself. Existing methods of describing this roughness and misalignment are reviewed and their shortcomings noted. A description is proposed which is valid in both statistical and wavelength-amplitude domains. Numerical data from the Tracked Hovercraft Ltd test track at Earith are analyzed and a mathematical model proposed for a typical commercial H.S.G.T. guideway. A method of computer generation of typical roughness profiles is discussed.

79-173

A Mathematical-Computer Simulation of the Dynamics of a Freight Element in a Railroad Freight Car

K.L. Shum and T. Willis

Dept. of Mech., Mechanical and Aerospace Engrg.,

Illinois Inst. of Tech., Chicago, IL, Rept. No. IIT-TRANS-75-2, FRA/ORD-77/28, 127 pp (July 1977) PB-282 308/6GA

Key Words: Freight cars, Railroad transportation, Mathematical models

This research studies the dynamic response of a freight element, inside a typical freight box car under service conditions, by a computer-model simulation technique. A 27 degree of freedom mathematical model has been developed to represent the freight car, truck and freight element, with the car body as a single rigid mass. This model has been validated against published railroad research data. This model is a more detailed one than most previously published simulations, and has additional characteristics. One is the option of modeling dry friction dampers by either Coulomb friction or equivalent viscous damping. A second improvement is the facility to express the response of the system in either time or frequency domain. The computer simulation shows that the critical roll mode speed of a representative 70-ton box car is around 17.5 mph. The maximum car body roll angle is 11.4 degrees peak to peak, the maximum wheel load is 69,000 lb/wheel, and wheel lift durations are 0.2 - 0.4 sec.

79-174

On the Effects of Inertia and Damping Factors of the Mechanical Guidance Upon the Running Stability of a Guided Vehicle

M. Matsui, M. Yamanouchi, T. Minami, and M. Watanabe

Advanced Design Dept., Toyo Kogyo Co., Ltd., Bull. JSME, 21 (158), pp 1250-1257 (Aug 1978) 12 figs, 3 refs

Key Words: Automated transportation, Control equipment, Inertial forces, Damping coefficients, Stability

To investigate the behavior of a running vehicle with automotive tires on the guideway, a simulation model is developed with a three dimensional model of the vehicle body and the guide mechanism with the inertia and dash-pots. The model is successfully compared with the experimental data of a test vehicle which was an automotive truck with the mechanical guidance. A characteristic equation is derived which is to be examined to explain the effects of the dynamical parameters of the guide mechanism such as inertia and damping factors on the running stability of the vehicle.

REACTORS

(Also see No. 143)

79-175

Simplified Derivation of the Reaction-Time History in Aircraft Impact on a Nuclear Power Plant

L.Y. Bahar and J.S. Rice

Dept. of Mech. Engrg. and Mechanics, Drexel Univ., Philadelphia, PA 19104, Nucl. Engr. Des., 49 (3), pp 263-268 (Sept 1968) 3 figs, 11 refs

Key Words: Nuclear power plants, Shock response, Aircraft

A simplified derivation of the reaction-time history in the case of an aircraft impacting a nuclear power plant is given. The equation of motion for the rigid part of the aircraft is obtained by considering it as a variable system of particles losing mass. The equation of motion for the crushing region is obtained by the methods of continuum mechanics.

79-176

Dynamic Response of Nuclear Power Plant Due to Earthquake and Aircraft Impact Including Effect of Soil-Structure Interaction

K.M. Ahmed and A.S. Ranshi

Water Reactor Div., Nuclear Power Co. (Risley), Ltd., Risley, Warrington WA3 6BZ, UK, J. Sound Vib., 59 (3), pp 423-440 (Aug 8, 1978) 14 figs, 5 tables, 15 refs

Key Words: Nuclear power plants, Earthquake response, Aircraft response, Finite element technique, Modal analysis, Interaction: soil-structure

A comparison is made of the dynamic response of a typical nuclear power plant to a modest earthquake (Parkfield) and to the impact of a small military aircraft (MRCA) and a large civil aircraft (Boeing 707-320). Finite element and modal superposition techniques are used to obtain the time-history response and the corresponding floor response spectra. The effect of soil-structure interaction is examined by varying the soil stiffness and damping over a range defined by soil shear wave velocities of 500 to 2000 m/second. A limited study is also carried out to assess the effect of embedment and foundation raft geometry on the seismic response of the structure.

RECIPROCATING MACHINE

(See No. 19)

ROAD

(Also see Nos. 12, 106, 162)

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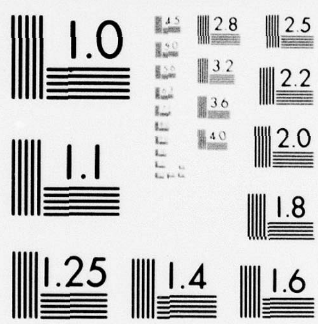

MICROCOPY RESOLUTION TEST CHART

79-177
Comparison of Methods for the Measurement of Wheel Load Variations (Vergleich von Verfahren zur Messung von Radlastschwankungen)

V. Gersbach, I. Schmid, and W. Rasch
Am Hang 21, 8081 Eching a.A., Automobiltech. Z., 80 (7/8), pp 353-356 (July/Aug 1978) 6 figs, 1 table, 12 refs
(In German)

Key Words: *Automobiles, Wheels, Dynamic tests*

The wheel load and its variations are valuable data in the determination of vehicle loads, especially in the design of axles and construction of roads. In addition, it is a measure of road contact and thus a safety measure. Presently there are no procedures available for measuring the dynamic wheel load directly on the vehicle during the ride. The paper describes a procedure for taking auxiliary data from which dynamic wheel data is derived. The procedure illustrates the shortcomings of the measurement techniques.

79-178
Reduction of Steering Wheel "Shimmy" (Untersuchung zur Reduzierung der Lenkungsunruhe)

G. Dodlbacher and H. Gaffke
Fasanenweg 4, 5024 Pulheim, Automobiltech. Z., 80 (7/8), pp 317-322 (July/Aug 1978) 14 figs, 3 refs
(In German)

Key Words: Wheel shimmy, Automobiles, Vibration control

A computer program for the determination of all parameters which influence the steering wheel shimmy was developed. The knowledge of all axial parameters, at least in the research phase, enabled the building of a low sensitivity front axle. The results obtained by computer were verified by experiment and the improvement in an actual vehicle was confirmed by subjective evaluation.

79-179
Investigation of Torsional Vibrations on Commercial Vehicles - Part 1 (Torsionsschwingungsuntersuchungen bei Nutzfahrzeugen)

E. Lauster and W. Maier
Spiegelberg 5, 7759 Immenstaad, Germany, Automobiltech. Z., 80 (7/8), pp 359-365 (July/Aug 1978) 12 figs, 17 refs
(In German)

Key Words: Automobiles, Ground vehicles, Drive shafts, Torsional vibration

An investigation of torsional vibrations of a vehicle driveline as a unit is considered. The first part is a theoretical discussion of natural frequencies and vibration exciting elements.

79-180
Vehicle Response to Stochastic Roadways

D.C. Karnopp
Dept. of Mech. Engrg., Univ. of California, Davis, CA 95616, Vehicle Syst. Dyn., 7 (2), pp 97-109 (Apr 1978) 2 figs, 6 refs

Key Words: Road roughness, Vehicle response

Dynamic response calculations for vehicles traversing irregular surfaces are usually accomplished using frequency domain methods involving spectral densities and transfer functions. Here an alternative procedure is developed which allows direct computation of mean square values and correlations of system variables for both transient and steady-state conditions. The method is based upon the differential equation for the covariance matrix which is directly related to the state equations for the vehicle. Multiple white noise inputs can be incorporated as well as inputs at two wheels which follow the same track at a distance from one another. The method is suitable for computer implementation without the complex algebra associated with finding all necessary transfer functions and the necessity of evaluating integrals in order to find mean square values using the conventional approach. As an illustration, a simple vehicle model is worked out completely and the variation of pitch and heave motion as a function of vehicle speed is plotted.

79-181
Measurement of Two Track Road Inputs and Theoretical Application of the Results (Messungen von Fahrbahn-Unebenheiten paralleler Fahrspuren und Anwendung der Ergebnisse)

V. Bormann
Institut f. Fahrzeugtechnik, Technische Universität Braunschweig, Vehicle Syst. Dyn., 7 (2), pp 65-81 (Apr 1978) 8 figs, 1 table
(In German)

Key Words: *Road roughness, Experimental data, Vehicle response*

The calculation of vehicle response to road-surface irregularity inputs requires the spectral densities of the left and right longitudinal track and their statistical dependence. This paper presents some results of parallel profile measurements,

three typical German roads have been chosen. Random vibration of two vehicle types are digital-simulated.

ROTORS

79-182

Transient Dynamics of a Flexible Rotor with Squeeze Film Dampers

D.F. Buono, L.D. Schlitzer, R.G. Hall, III, and D.H. Hibner
United Technologies Corp., Pratt & Whitney Aircraft, East Hartford, CT 06108, Rept. No. NASA-CR-3050, 83 pp (Sept 1978)

Key Words: Flexible rotors, Blade loss dynamics, Transient response, Squeeze-film dampers

This report contains the results of an experimental and analytical investigation of the transient response of a flexible rotor with squeeze film dampers. The experimental part of the program consisted of a series of simulated blade loss tests on a test rotor designed to operate above its second bending critical speed. The analytical part of the program comprised a series of analyses which predicted the transient behavior of the test rig for each of the blade loss tests. The scope of the program included the investigation of transient rotor dynamics of a flexible rotor system, similar to modern flexible jet engine rotors, both with and without squeeze film dampers. The results substantiate the effectiveness of squeeze film dampers and document the ability of available analytical methods to predict their effectiveness and behavior.

79-183

Experimental Investigation of Gust Response of Hingeless Helicopter Rotors

C.A. Vehlow
Dept. of Aeronautics and Astronautics, Massachusetts Inst. of Tech., Cambridge, MA, 105 pp (June 1977)
AD-A054 752/1GA

Key Words: Helicopter rotors, Wind-induced excitation, Wind tunnel tests

The response to wind gusts of a 1/10-scale hingeless helicopter rotor model in hovering and forward flight is studied experimentally through wind tunnel testing. The experimental program involving design, construction, and testing of a five-foot-diameter rotor utilizing either three NACA 0012 planform blades or one operable blade with two dummy blades is described. The rotor design is such that the torsional stiffness of the blade assembly as well as the blade chordwise center-of-gravity location can be varied during the various phases of the test. Wind tunnel testing incorporates the variation of wind tunnel speed and the application of variable frequency, sinusoidal waveform gusts. The flap, lag, and torsional response of the rotor in its various configurations was measured and compared with theoretical predictions.

SHIP

79-184

Some New Aspects of Slamming Probability Theory

H.N. Psaraftis
Dept. of Ocean Engrg., Massachusetts Inst. of Tech., Cambridge, MA, J. Ship Res., 22 (3), pp 186-192 (Sept 1978) 4 figs, 15 refs

Key Words: Ships, Slamming, Probability theory

A systematic investigation of some probabilistic aspects of slamming is presented. This investigation includes the assessment of the unconditional probability of slamming at a random instant of time; the estimation of the conditional probability of slamming at a given instant after a particular slam; and the consequent rejection of the hypothesis that slamming is a Poisson process. In addition, a procedure to approximate the distribution of slamming interarrival times is presented. Finally, new slamming statistics, obtainable from the theory of this work, are presented and compared with the existing slamming criteria. The theory of this paper can be readily applied to other seakeeping events such as deck wetness, keel emergence, and propeller racing.

79-185

A Note on the Form of Ship Roll Damping

J.F. Dalzell
Davidson Lab., Stevens Inst. of Tech., Hoboken, NJ, J. Ship Res., 22 (3), pp 178-185 (Sept 1978) 14 figs, 1 table, 22 refs

Key Words: Ships, Ship rolling

The objective of the present work was to develop an approximation to the conventional mixed linear-plus-quadratic ship roll damping model so that analytical obstacles could be overcome in the application of the functional series expansion to nonlinear ship rolling. A mixed linear-plus-cubic approximation was found to be reasonable for this purpose. In the course of analyses, there were indications that this model may be closer to an "equivalent approach" than to an "approximation".

79-186

Nonlinear Resonant Excitation of a Long and Narrow Bay

S.R. Rogers and C.C. Mei

Dept. of Appl. Mathematics, Weizmann Inst. of Science, Israel, J. Fluid Mech., 88 (1), pp 161-180 (Sept 13, 1978) 5 figs, 2 tables, 23 refs

Key Words: Harbors, Water waves, Resonant response

A nonlinear study of harbor resonance is carried out for a rectangular bay indented from a straight coast. Boussinesq equations with nonlinearity and dispersion are used. Simplifying approximations are made for a narrow bay to decouple the nonlinear problem in the bay from the approximately linear problem in the ocean. Harmonic generation in the bay is studied numerically. Experiments for three different bay lengths and three amplitudes are compared with the numerical theory. The relative importance of entrance loss and boundary-layer dissipation to nonlinearity is estimated.

SPACECRAFT

(Also see No. 125)

79-187

Acoustics or Shakers for Simulation of Captive Flight Vibration

A.M. Spandrio and M.E. Burke

Pacific Missile Test Center, Point Mugu, CA., Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 5-14 (Sept 1978) 11 figs

Key Words: Missiles, Flight simulation, Vibration response

Laboratory simulation of the failure producing vibration loads to which air-launched missiles are exposed in the captive flight environment has become an important cost effective test method. For the test to be valid, simulation of the failure rate and types of failures produced must be the same as those produced in captive flight. This paper compares two methods that are currently being used to simulate the captive flight vibration loads the PHOENIX missile experiences on the F-14 aircraft. A dual shaker vibration facility was developed for captive flight simulation as part of the PHOENIX GLAT program. Captive flight simulation using acoustical excitation will be used as part of the PHOENIX Logistics Engineering Improvement Program (LEIP). PHOENIX captive flight vibration response was discussed in terms of direction, spatial and spectral distribution, and then compared to the missile vibration response achieved in the laboratory by the two aforementioned methods. Missile captive flight data was obtained from the PHOENIX T-1/F-14A Flight Test Program and the PHOENIX/F-14 Captive Flight Vibration Measurement Program. In these programs the PHOENIX T-201 Environmental Measurements Missile were used. This same missile was subjected to captive flight simulation using the dual shaker vibration and acoustical vibration.

79-188

A Mathematical Method for Determining a Laboratory Simulation of the Captive-Flight Vibrational Environment

S. Ogden

Pacific Missile Test Center, Point Mugu, CA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 1-4 (Sept 1978) 2 figs, 3 tables, 4 refs

Key Words: Missiles, Flight simulation, Vibration response

The captive-flight vibrational environment of a missile can be simulated by laboratory induced vibration. The captive-flight vibration levels can be shown to be directly proportional to the dynamic pressure (q) levels. Typically, the captive-flight conditions, combinations of mach number and altitude, can be summarized as a discrete function of time over the entire range of q levels. This paper describes a method for selecting a small number of discrete q levels and associated test time at each level which represents the given captive-flight conditions.

79-189

Turbulent-Boundary-Layer Excitation and Response Thereto for a High-Performance Conical Vehicle

C.M. Ailman

McDonnell Douglas Astro. Corp., Los Angeles, CA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 159-169 (Sept 1978) 10 figs, 1 table, 9 refs

Key Words: Reentry vehicles, Conical shells, Beams, Vibration response

Ground and flight test data from a high-performance maneuverable vehicle called ACE suggest several revisions to the empiricisms used to develop dynamic environmental criteria for RV's. Part I of this paper includes a compiled data bank for describing the fluctuating pressures that force the shell of a non-maneuvering RV to vibrate during reentry, and a discussion on the use of a local aerodynamic parameter values for the cone when predicting these pressures, and a description of the characteristics of shell-mode vibration peculiar to a conical structure with a multilayered skin. Part II reports flight data from such a structure when maneuvering as a result of flow disturbance at the aft end. The beam response is analytically examined as to its probable cause.

79-190

Use of Shock Spectra to Evaluate Jitter of a Flexible Maneuvering Spacecraft

W.J. Kacena

Martin Marietta Corp., Denver, CO, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 3, pp 39-47 (Sept 1978) 7 figs, 2 tables, 2 refs

Key Words: Spacecraft equipment response, Shock response spectra

Structural dynamic analysts are responsible for evaluating the effects of vibration on the operation of displacement sensitive spacecraft instruments. One example is an optical pointing instrument that is vibrating because an orbital maneuver has just been performed. This paper shows that a residual displacement shock spectrum of the rotational acceleration time history defines the vibration modes and the maneuvers which are critical to pointing accuracy. In addition, several realistic maneuvers are discussed and their effects on vibration are compared.

79-191

Transfer Function Applications to Spacecraft Structural Dynamics

J.R. Fowler and E. Dancy

Hughes Aircraft Co., El Segundo, CA, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 1, pp 93-101 (Sept 1978) 14 figs, 2 tables, 2 refs

Key Words: Spacecraft, Fast Fourier transforms, Modal analysis

Fast Fourier transform computed transfer functions are used for several spacecraft applications. An Intelsat IVA spacecraft was tested using several excitations and the resulting transfer functions are compared using modal frequencies and damping. An example of mass and stiffness computations from transfer functions is presented. Use of alternative reference points for the transfer functions is presented. An example of the use of slight changes in transfer functions to detect failures is shown.

79-192

Calculation of Attach Point Loads Due to Possible Combustion Instability in the Space Shuttle Solid Rocket Boosters

F.R. Jensen and D.T. Wang

Hercules Incorporated, Magna, UT, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 4, pp 171-174 (Sept 1978)

Key Words: Space shuttles, Acoustic excitation, Combustion excitation

The Space Shuttle vehicle was analyzed to determine structural response to possible acoustic combustion instability in the solid rocket boosters. Response of the Space Shuttle vehicle to pressure oscillations in the solid rocket boosters (SRB's) was calculated and expressed in terms of forces and displacements at the attach points between the SRB's and the External Tank (ET), and between the ET and the orbiter. The NASTRAN computer program was used to analyze various finite element shuttle models. A detailed finite element model of the solid rocket motor (SRM) was constructed for use with the cyclic symmetry option in NASTRAN. The models were analyzed separately and results were combined to represent the total structure by using a mechanical impedance-type approach. Acoustic analyses were performed at the Naval Weapons Center (NWC) at China Lake, California. The acoustic natural frequencies and mode shapes were transmitted to Hercules for use in this analysis program. The analysis approach based on using mechanical impedance methods and the cyclic symmetry option in NASTRAN was demonstrated by calculating shuttle structure response to the first longitudinal acoustic mode in the SRB's.

79-193

Rocket Motor Response to Transverse Blast Loading

N.J. Huffington, Jr. and H.L. Wisniewski

U.S. Army Ballistic Res. Lab., Aberdeen Proving Ground, MD, Shock Vib. Bull., U.S. Naval Res. Lab., Proc., Vol. 48, Pt. 3, pp 21-32 (Sept 1978) 15 figs, 2 tables, 5 refs

Key Words: Solid propellant rocket motors, Air blast, Blast response, Computer programs

The effects of propellant inertia and of internal pressurization on the structural response of solid propellant rocket motors subjected to transverse air blast loading have been investigated, both analytically and numerically. The numerical predictions were accomplished using the BRL version of the PETROS 3.5 computer program, which employs the finite difference method to solve the equations governing finite amplitude elastoplastic response of thin shells. The response of a typical rocket motor configuration was calculated for the limiting situations of the bare motor case and of the motor case containing the complete propellant grain, each with no internal pressurization and with the pressurization resulting from propellant combustion.

TRANSMISSIONS

79-194
Helicopter Transmission Vibration and Noise Reduction Program. Volume 1. Technical Report

J.J. Sciarra, R.W. Howells, J.W. Lenski, Jr., R.J. Drago, and E.G. Schaeffer
Boeing Vertol Co., Philadelphia, PA, Rept. No. D210-11236-1, USARTL-TR-78-2A, 307 pp (Mar 1978)
AD-A055 104/4GA

Key Words: Power transmission systems, Helicopter engines, Vibration control, Noise reduction, Computer programs

The objective of the helicopter transmission vibration noise reduction program was to generate analytical tools for the prediction and reduction of helicopter transmission vibration/noise that provide the capability to perform trade studies during the design stage of a program. Application of this optimization capability yields drive train components that are dynamically quiet with reduced vibration/noise levels and inherently longer life.

79-195
A Semi-Analytic Approach to the Dynamic Simulation of Shaft Coupled Power Transmission Systems

D.E. Bowns and S.A. Huckvale
School of Engrg., Fluid Power Centre, Univ. of Bath, Instn. Mech. Engr. Proc., 192, pp 125-133 (June 1978) 7 figs, 5 refs

Key Words: Power transmission systems, Mathematical models

In simulating complex power transmission systems it is an advantage to employ separately developed sub-models of the various components. There are, however, major difficulties in assembling such models into a complete system simulation. This paper discusses the problem and presents the concept of energy storage for linking adjacent sub-models. It develops the method to deal with systems coupled by shafts.

USEFUL APPLICATION

79-196
Self-Sustained Oscillations of Organ Flue Pipes: An Integral Equation Solution

R.T. Schumacher
Dept. of Physics, Carnegie-Mellon Univ., Pittsburgh, PA 15213, Acustica, 39 (4), pp 225-238 (Mar 1978) 11 figs, 1 table, 14 refs

Key Words: Musical instruments, Pipes (tubes), Self-excited vibrations

The oscillations of an organ pipe are described in terms of a non-linear equation of the Hammerstein type. Approximate solutions involving two and three harmonics are used as initial approximations for an iterative numerical solution of the full integral equation. The approximate solutions are shown to satisfy a "regeneration condition" that are then found to be satisfied by the full numerical solutions. Sample solutions are obtained for a number of different parameters of the pipe and are found to agree with the qualitative observations that exist. However, the results are so rich in predictive detail that available data are inadequate to test in detail the model used in these calculations.

79-197
The Analysis of Multiple Resonance in a Vibrating Mechanical System by the Use of the Electrical Transmission Line Analogy

R.J. Clarke
Dept. of Electronic and Electrical Engrg., Loughborough Univ. of Tech., Loughborough, Leicestershire, UK, Acustica, 40 (1), pp 34-39 (Apr 1978) 4 figs, 5 refs

Key Words: Mechanical systems, Strings, Plates, Musical instruments, Multiple resonance, Resonant frequency

The use of analogies from electrical circuit theory often provides a powerful method of analyzing vibrating mechanical systems. In the present case a structure is considered consisting of a stretched string vibrating in its lowest mode, and terminated in a plate having one predominant mode of resonance at a frequency near to that of the string. In its electrical form the structure consists of a transmission line section terminated in a series tuned circuit, and the analysis determines the critical value of the parameters of such a structure in order that multiple resonance shall occur. Such a mechanical structure forms the basis of the family of string musical instruments in which, under certain circumstances determined in the present analysis, the phenomenon of multiple resonance occurs as a practical problem for the performer.

79-198
Violin Timbre and Bridge Frequency Response

M. Hacklinger
Gauting, Federal Republic of Germany, Acustica, 39 (5), pp 323-330 (Apr 1978) 10 figs, 4 refs

Key Words: Violins, Musical instruments, Frequency response method, Experimental data

The frequency response of complete violins and of isolated bridges has been measured at very small amplitudes by harmonic excitation of the damped strings and recording of lateral bridge top movement. Bridge response curves have been obtained by mounting the bridge on a "mute violin" where the bridge base was completely rigid. It was found that below 1000 Hz the elastic properties of the bridge have little influence on total vibration whereas between 1 and 3 kHz the bridge exhibits pronounced resonance peaks with a strong influence on violin timbre. The measured decrease of bridge natural frequency with additional masses at the bridge top agrees well with theoretical prediction for a simple mass-spring-model. By measuring bridge stiffness for the fundamental vibration mode and bridge frequency response of different specimens, correlations have been established between the geometric and elastic properties of the bridge and their influence on violin timbre. The results have been applied to a large number of instruments with consistent results of violin timbre changes.

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TECHNICAL NOTES

G. Ahmadi and N. Mostaghel
On the Stability of Columns Subjected to Non-Stationary Random or Deterministic Support Motion
Intl. J. Earthquake Engr. Struc. Dynam., 6 (3), pp 321-326 (May/June 1978) 16 refs

B.S. Berger
Steady-State Motion of a Shell of Revolution in an Acoustic Medium
J. Appl. Mech., Trans. ASME, 45 (2), pp 447-448 (June 1978) 2 figs, 7 refs

W. Hauger
On the Dynamic Behaviour of Dissipative Circulatory Structural Systems
J. Sound Vib., 56 (4), pp 575-581 (Feb 22, 1978) 4 figs, 5 refs

C.S. Tsay and J.N. Reddy
Bending, Stability and Free Vibration of Thin Orthotropic Plates by Simplified Mixed Finite Elements
J. Sound Vib., 59 (2), pp 307-311 (July 22, 1978) 4 tables, 10 refs

P. Biswas
Thermally-Induced Vibrations of a Triangular Slab Resting on Elastic Foundation
J. Sound Vib., 59 (2), pp 304-306 (July 22, 1978) 2 figs, 3 refs

G. Edlund, G. Wikander, and N.-E. Molin
The Visualization of Modes in a Circular Cochlear Model by Hologram Interferometry
J. Sound Vib., 59 (2), pp 299-303 (July 22, 1978) 4 figs, 12 refs

G. Prathap
On the Large Amplitude Vibration of Circular Cylindrical Shells
J. Sound Vib., 59 (2), pp 295-298 (July 22, 1978) 12 refs

Z. Celep
On the Stability of a Discrete Model of the Free-Free Beam Subjected to End-Loads
J. Sound Vib., 59 (1), pp 153-157 (July 8, 1978) 3 figs, 7 refs

K. Raju and G.V. Rao
Effect of Initial Thermal Stresses on the Large Amplitude Vibrations of Circular Plates
J. Sound Vib., 59 (1), pp 150-152 (July 8, 1978) 2 tables, 5 refs

K. Kawatate
A Vibration Analysis of an Underwater Beam with Circular Section
J. Sound Vib., 59 (1), pp 147-149 (July 8, 1978) 1 fig, 6 refs

S.M. Dickinson
On the Use of Simply Supported Plate Functions in Rayleigh's Method Applied to the Flexural Vibration of Rectangular Plates
J. Sound Vib., 59 (1), pp 143-146 (July 8, 1978) 2 tables, 2 refs

PERIODICALS SCANNED

PUBLICATION AND ADDRESS	ABBREVIATION
ACTA MECHANICA Springer-Verlag New York Inc. 175 Fifth Ave. New York, NY 10010	Acta. Mech.
ACUSTICA S. Hirzel Verlag, Postfach 347 D-700 Stuttgart 1 W. Germany	Acustica
AERONAUTICAL JOURNAL Royal Aeronautical Society 4 Hamilton Place London, W1V 0BQ, UK	Aeronaut. J.
AERONAUTICAL QUARTERLY Royal Aeronautical Society 4 Hamilton Place London W1V 0BQ, UK	Aeronaut. Quart.
AIAA JOURNAL American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	AIAA J.
AMERICAN SOCIETY OF CIVIL ENGINEERS, PROCEEDINGS Publications Office, ASCE United Engineering Center 345 East 47th St. New York, NY 10017	
JOURNAL OF ENGINEERING MECHANICS DIVISION	ASCE J., Engr. Mech. Div.
JOURNAL OF ENVIRONMENTAL ENGINEERING DIVISION	ASCE J., Environ. Engr. Div.
JOURNAL OF GEOTECHNICAL ENGINEERING DIVISION	ASCE J., Geotech. Engr. Div.
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JOURNAL OF TRANSPORTATION ENGINEERING DIVISION	ASCE J., Transport. Engr. Div.
AMERICAN SOCIETY OF LUBRICATING ENGINEERS, TRANSACTIONS Academic Press 111 Fifth Ave. New York, NY 10019	ASLE, Trans.
AMERICAN SOCIETY OF MECHANICAL ENGINEERS, TRANSACTIONS United Engineering Center 345 East 47th St. New York, NY 10017	
JOURNAL OF APPLIED MECHANICS	J. Appl. Mech., Trans. ASME
JOURNAL OF DYNAMIC SYSTEMS, MEASUREMENT AND CONTROL	J. Dyn. Syst., Meas. and Control, Trans. ASME
JOURNAL OF ENGINEERING FOR INDUSTRY	J. Engr. Indus. Trans. ASME
JOURNAL OF ENGINEERING FOR POWER	J. Engr. Power, Trans. ASME
JOURNAL OF LUBRICATION TECHNOLOGY	J. Lubric. Tech. Trans. ASME
APPLIED ACOUSTICS Applied Science Publishers, Ltd. Ripple Road, Barking Essex, UK	Appl. Acoust.
APPLIED MATHEMATICAL MODELING IPC House 32 High St., Guildford Surrey GU1 3EW, UK	Appl. Math. Modeling
ARCHIVE FOR RATIONAL MECHANICS AND ANALYSIS Springer-Verlag, New York, Inc. 175 Fifth Ave. New York, NY 10010	Arch. Rational Mech. Anal.
ARCHIVES OF MECHANICS (ARCHIWUM MECHANIKI STOSOWANEJ) Export and Import Enterprise Ruch UL, Wronia 23, Warsaw, Poland	Arch. Mech. Stosowanej
ASTRONAUTICS AND AERONAUTICS AIAA EDP 1290 Avenue of the Americas New York, NY 10019	Astronaut. & Aeronaut.
AUTOMOBILTECHNISCHE ZEITSCHRIFT Franckh'sche Verlagshandlung Abteilung Technik 7000 Stuttgart 1, Pfizerstrasse 5-7 W. Germany	Automobiltech. Z.
AUTOMOTIVE ENGINEER P. O. Box 24, Northgate Ave. Bury St., Edmunds Suffolk IP32 GBW, UK	Auto. Engr.
BALL BEARING JOURNAL (English Edition) SKF (U.K.) Ltd. Luton, Bedfordshire LU3 1JF, UK	Ball Bearing J.

PUBLICATION AND ADDRESS	ABBREVIATION
BAUINGENIEUR S. Hirtzel Verlag, Postfach 347 D-700 Stuttgart 1, W. Germany	Bauingenieur
BROWN BOVERI REVIEW Brown Boveri and Co., Ltd. CH-5401, Baden, Switzerland	Brown Boveri Rev.
BULLETIN DE L'ACADEMIE POLONAISE DES SCIENCES, SERIES DES SCIENCES TECHNIQUES Ars Polona-Ruch 7 Krokowskie Przedmiescie, Poland	Bull. Acad. Polon. Sci., Ser. Sci. Tech.
BULLETIN OF THE FACULTY OF ENGINEERING, YOKAHAMA NATIONAL UNIVERSITY Yokahama National University OHKA-MACHI, Minami-ku Yokahama, Japan	Bull. Fac. Eng. Yokahama Natl. Univ.
BULLETIN OF JAPAN SOCIETY OF MECHANICAL ENGINEERS Japan Society of Mechanical Engineers Sanshin Hokusei Bldg. H-9 Yoyogi 2-chome Shibuya-ku Tokyo 151, Japan	Bull. JSME
BULLETIN OF SEISMOLOGICAL SOCIETY OF AMERICA Bruce A. Bolt Box 826 Berkeley, CA 94705	Bull. Seismol. Soc. Amer.
CHEMICAL PROCESSING Putnam Publishing Co. 430 N. Michigan Ave. Chicago, IL 60611	Chem. Processing
CIVIL ENGINEERING (NEW YORK) ASCE Publications Office 345 E. 47th St. New York, NY 10017	Civ. Engr. (N.Y.)
CLOSED LOOP MTS Systems Corp. P. O. Box 24012 Minneapolis, MN 55424	Closed Loop
COMPUTERS AND STRUCTURES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Computers Struc.
DESIGN NEWS Cahners Publishing Co., Inc. 221 Columbus Ave. Boston, MA 02116	Des. News
DIESEL AND GAS TURBINE PROGRESS Diesel Engines, Inc. P. O. Box 7406 Milwaukee, WI 53213	Diesel Gas Turbine Prog.
ENGINEERING MATERIALS AND DESIGN IPC Industrial Press Ltd. 33-40 Bowling Green Lane London EC1R, UK	Engr. Matl. Des.

PUBLICATION AND ADDRESS	ABBREVIATION
EXPERIMENTAL MECHANICS Society for Experimental Stress Analysis 21 Bridge Sq., P. O. Box 277 Westport, CT 06880	Exptl. Mech.
FORSCHUNG IM INGENIEURWESEN Verein Deutscher Ingenieur, GmbH Postfach 1139, Graf-Recke Str. 84 4 Duesseldorf 1, W. Germany	Forsch. Ingenieurw.
HEATING/PIPING/AIR CONDITIONING Circulation Dept. 614 Superior Ave. West Cleveland, OH 44113	Heating/ Piping/ Air Cond.
HIGH-SPEED GROUND TRANSPORTATION JOURNAL Planning Transportation Assoc., Inc. P. O. Box 4824, Duke Station Durham, NC 27706	High-Speed Ground Transp. J.
HYDROCARBON PROCESSING Gulf Publishing Co. Box 2608 Houston, TX 77001	Hydrocarbon Processing
HYDRAULICS AND PNEUMATICS Penton/IPC, Inc. 614 Superior Ave., West Cleveland, OH 44113	Hydraulics & Pneumatics
IBM JOURNAL OF RESEARCH AND DEVELOPMENT International Business Machines Corp. Armonk, NY 10504	IBM J. Res. Dev.
INDUSTRIAL RESEARCH Dun-Donnelley Publishing Corp. 222 S. Riverside Plaza Chicago, IL 60606	Indus. Res.
INGENIEUR-ARCHIV Springer-Verlag New York, Inc. 175 Fifth Ave. New York, NY 10010	Ing. Arch.
INSTITUTION OF MECHANICAL ENGINEERS, (LONDON), PROCEEDINGS Institution of Mechanical Engineers 1 Birdcage Walk, Westminister, London SW1, UK	Instn. Mech. Engr. Proc.
INSTRUMENT SOCIETY OF AMERICA, TRANSACTIONS Instrument Society of America 400 Stanwix St. Pittsburgh, PA 15222	ISA Trans.
INTERNATIONAL JOURNAL OF CONTROL Taylor and Francis Ltd. 10-14 Macklin St. London WC2B 5NF, UK	Intl. J. Control
INTERNATIONAL JOURNAL OF EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS John Wiley and Sons, Ltd. 650 Third Ave. New York, NY 10016	Intl. J. Earthquake Engr. Struc. Dynam.

PUBLICATION AND ADDRESS	ABBREVIATION
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Engr. Sci.
INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH Pergamon Press, Inc. Maxwell House, Fairveiw Park Elmsford, NY 10523	Intl. J. Mach. Tool Des. Res.
INTERNATIONAL JOURNAL OF MECHANICAL SCIENCES Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Mech. Sci.
INTERNATIONAL JOURNAL OF NONLINEAR MECHANICS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Nonlin. Mech.
INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING John Wiley and Sons, Ltd. 605 Third Ave. New York, NY 10016	Intl. J. Numer. Methods Engr.
INTERNATIONAL JOURNAL FOR NUMERICAL AND ANALYTICAL METHODS IN GEOMECHANICS John Wiley and Sons, Ltd. Baffins Lane Chichester, Sussex, UK	Intl. J. Numer. Anal. Methods Geomech.
INTERNATIONAL JOURNAL OF SOLIDS AND STRUCTURES Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Solids Struc.
ISRAEL JOURNAL OF TECHNOLOGY Weizmann Science Press of Israel Box 801 Jerusalem, Israel	Israel J. Tech.
JOURNAL DE MÉCANIQUE Gauthier-Villars 55 Quai des Grands Augustines, Paris 6, France	J. de Mécanique
JOURNAL DE MÉCANIQUE APPLIQUÉE Gauthier-Villars 55 Quai des Grands Augustines, Paris 6, France	J. de Mécanique Appl.
JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA American Institute of Physics 335 E. 45th St. New York, NY 10010	J. Acoust. Soc. Amer.
JOURNAL OF AIRCRAFT American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Aircraft

PUBLICATION AND ADDRESS	ABBREVIATION
JOURNAL OF THE AMERICAN HELICOPTER SOCIETY American Helicopter Society, Inc. 30 E. 42nd St. New York, NY 10017	J. Amer. Helicopter Soc.
JOURNAL OF COMPOSITE MATERIALS Technomic Publishing Co., Inc. 750 Summers St. Stamford, CT 06901	J. Composite Matl.
JOURNAL OF ENGINEERING MATHEMATICS Academic Press 198 Ash Street Reading, MA 01867	J. Engr. Math.
JOURNAL OF ENVIRONMENTAL SCIENCES Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	J. Environ. Sci.
JOURNAL OF FLUID MECHANICS Cambridge University Press 32 East 57th St. New York, NY 10022	J. Fluid Mech.
JOURNAL OF THE FRANKLIN INSTITUTE Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Franklin Inst.
JOURNAL OF THE INSTITUTE OF ENGINEERS, AUSTRALIA Science House, 157 Gloucter Sydney, Australia 2000	J. Inst. Engr., Australia
JOURNAL OF MECHANICAL ENGINEERING SCIENCE Institution of Mechanical Engineers 1 Birdcage Walk, Westminister London SW1 H9, UK	J. Mech. Engr. Sci.
JOURNAL OF THE MECHANICS AND PHYSICS OF SOLIDS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Mech. Phys. Solids
JOURNAL OF PHYSICS E. (SCIENTIFIC INSTRUMENTS) American Institute of Physics 335 East 45th St. New York, NY 10017	J. Phys. E. (Sci. Instr.)
JOURNAL OF SHIP RESEARCH Society of Naval Architects and Marine Engineers 20th and Northhampton Sts. Easton, PA 18042	J. Ship Res.
JOURNAL OF SOUND AND VIBRATION Academic Press 111 Fifth Ave. New York, NY 10019	J. Sound Vib.

PUBLICATION AND ADDRESS	ABBREVIATION
JOURNAL OF SPACECRAFT AND ROCKETS American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Space-craft Rockets
JOURNAL OF TESTING AND EVALUATION (ASTM) American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103	J. Test Eval.
KONSTRUKTION Springer Verlag 3133 Connecticut Ave., N.W. Suite 712 Washington, D.C. 20008	Konstruktion
LUBRICATION ENGINEERING American Society of Lubrication Engineers 838 Busse Highway Park Ridge, IL 60068	Lubric. Engr.
MACHINE DESIGN Penton Publishing Co. Penton Bldg. Cleveland, OH 44113	Mach. Des.
MASCHINENBAUTECHNIK VEB Verlag Technik Oranienburger Str. 13/14 102 Berlin, E. Germany	Maschinen-bautechnik
MECCANICA Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Meccanica
MECHANICAL ENGINEERING American Society of Mechanical Engineers 345 E. 45th St. New York, NY 10017	Mech. Engr.
MECHANICAL ENGINEERING, TRANSACTIONS, THE INSTITUTION OF ENGINEERS, AUSTRALIA The Institution of Engineers, Australia 11 National Circuit Barton, A.C.T. 2600	Instn. Mech. Engr., Australia, Mech. Engr. Trans.
MECHANICS RESEARCH AND COMMUNICATIONS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mech. Res. Comm.
MECHANISM AND MACHINE THEORY Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mech. Mach. Theory
MEMOIRES OF THE FACULTY OF ENGINEERING, KYOTO UNIVERSITY Kyoto University Kyoto, Japan	Mem. Fac. Engr. Kyoto Univ.
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MTZ MOTORTECHNISCHE ZEITSCHRIFT Frankh'sche Verlagshandlung Pfizerstrasse 5-7 7000 Stuttgart 1, W. Germany	MTZ Motor-tech. Z.
NAVAL ENGINEERS JOURNAL American Society of Naval Engineers, Inc. Suite 507, Continental Bldg. 1012 - 14th St., N.W. Washington, D.C. 20005	Naval Engr. J.
NOISE CONTROL VIBRATION ISOLATION Trade and Technical Press Ltd. Crown House, Morden Surrey SM4 5EW, UK	Noise Control Vib. Isolation
NOISE CONTROL ENGINEERING P. O. Box 2167 Morristown, NJ 07960	Noise Control Engr.
NORTHEAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS, TRANSACTIONS Bolbec Hall, Newcastle Upon Tyne 1, UK	NE Coast Instn. Engrs. Shipbldrs., Trans.
NUCLEAR ENGINEERING AND DESIGN North Holland Publishing Co. P. O. Box 3489 Amsterdam, The Netherlands	Nucl. Engr. Des.
OIL AND GAS JOURNAL The Petroleum Publishing Co. 211 S. Cheyenne Tulsa, OK 74101	Oil Gas J.
OSAKA UNIVERSITY, TECHNICAL REPORTS Faculty of Technology Osaka University Miyakojima, Osaka, Japan	Osaka Univ., Tech. Rept.
PACKAGE ENGINEERING 5 S. Wabash Ave. Chicago, IL 60603	Package Engr.
PHYSICS TODAY American Institute of Physics, Inc. 335 East 45th St. New York, NY 10017	Physics Today
POWER P. O. Box 521 Hightston, NJ 08520	Power
POWER TRANSMISSION DESIGN Industrial Publishing Co. Division of Pittway Corp. 812 Huron Rd. Cleveland, OH 44113	Power Transm. Des.
PRODUCT ENGINEERING (NEW YORK) McGraw-Hill Book Co. P. O. Box 1622 New York, NY	Product Engr. (NY)
QUARTERLY JOURNAL OF MECHANICS AND APPLIED MATHEMATICS Wm. Dawson & Sons, Ltd. Cannon House Folkestone, Kent, UK	Quart. J. Mech. Appl. Math.

PUBLICATION AND ADDRESS	ABBREVIATION
REVUE ROUMAINE DES SCIENCES TECHNIQUES, SERIE DE MÉCANIQUE APPLIQUEE Editions De L'Academie De La Republique Socialiste de Roumanie 3 Bis Str., Gutenberg, Bucurest, Romania	Rev. Roumaine Sci. Tech., Mécanique
REVIEW OF SCIENTIFIC INSTRUMENTS American Institute of Physics 335 East 45th St. New York, NY 10017	Rev. Scientific Instr.
SAE PREPRINTS Society of Automotive Engineers Two Pennsylvania Plaza New York, NY 10001	SAE Prepr.
SIAM JOURNAL ON APPLIED MATHEMATICS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Appl. Math.
SIAM JOURNAL ON NUMERICAL ANALYSIS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Numer. Anal.
SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, NEW YORK, TRANSACTIONS Society of Naval Architects and Engineers 20th and Northhampton St. Easton, PA 18042	Soc. Naval Arch. Mar. Engr., Trans.
S/V, SOUND AND VIBRATION Acoustic Publications, Inc. 27101 E. Oviat Rd. Bay Village, OH 44140	S/V, Sound Vib.
TECHNISCHES MESSEN - ATM R. Oldenburg Verlag GmbH Rosenheimer Str. 145 8 München 80, W. Germany	Techn. Messen

PUBLICATION AND ADDRESS	ABBREVIATION
TRANSACTIONS OF THE INSTRUMENT SOCIETY OF AMERICA Instrument Society of America 400 Standix St. Pittsburgh, PA 15222	Trans. Instr. Soc. Amer.
TURBOMACHINERY INTERNATIONAL Turbomachinery Publications, Inc. 22 South Smith St. Norwalk, CT 06855	Turbomach. Intl.
VDI ZEITSCHRIFT Verein Deutscher Ingenieur GmbH Postfach 1139, Graf-Recke Str. 84 4 Duesseldorf 1, Germany	VDI Z.
VEHICLE SYSTEMS DYNAMICS Swets and Zeitlinger N.V. 347 B. Herreweg Lisse, The Netherlands	Vehicle Syst. Dyn.
VIBROTECHNIKA Kauno Polytechnikos Institutas Kaunas, Lithuania	Vibro-technika
WEAR Elsevier Sequoia S.A. P. O. Box 851 1001 Lausanne 1, Switzerland	Wear
ZEITSCHRIFT FÜR ANGEWANDTE MATHEMATIK UND MECHANIK Akademie Verlag GmbH Liepziger Str. 3-4 108 Berlin, Germany	Z. angew. Math. Mech.
ZEITSCHRIFT FÜR FLUGWISSENSCHAFTEN DFVLR D-3300 Braunschweig Flughafen, Postfach 3267 W. Germany	Z. Flugwiss

ANNUAL PROCEEDINGS SCANNED

INTERNATIONAL CONGRESS ON ACOUSTICS, ANNUAL PROCEEDINGS	Intl. Cong. Acoust., Proc.
INSTITUTE OF ENVIRONMENTAL SCIENCES, ANNUAL PROCEEDINGS Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	Inst. Environ. Sci., Proc.
MIDWESTERN CONFERENCE ON SOLID MECHANICS, ANNUAL PROCEEDINGS	Midw. Conf. Solid Mech. Proc.
THE SHOCK AND VIBRATION BULLETIN, UNITED STATES NAVAL RESEARCH LABORATORIES, ANNUAL PROCEEDINGS Shock and Vibration Information Center Naval Research Lab., Code 8404 Washington, D.C. 20375	Shock Vib. Bull., U.S. Naval Res. Lab., Proc.
UNITED STATES CONGRESS ON APPLIED MECHANICS, ANNUAL PROCEEDINGS	U.S. Cong. Appl. Mech., Proc.
WORLD CONGRESS ON APPLIED MECHANICS, ANNUAL PROCEEDINGS	World Cong. Appl. Mech., Proc.

CALENDAR

FEBRUARY 1979

26-Mar 2 Congress & Exposition, [SAE] Cobo Hall, Detroit, MI *(SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096)*

MARCH 1979

12-15 Gas Turbine Conference and Exhibit, [ASME] San Diego, CA *(ASME Hq.)*

APRIL 1979

4-6 Structures, Structural Dynamics and Materials Conference, [AIAA-ASME] Chase-Park Plaza Hotel, St. Louis, MO *(ASME Hq.)*

30-May 2 NOISE-CON 79, [INCE] Purdue University, IN *(NOISE-CON 79, 116 Stewart Center, Purdue University, West Lafayette, IN 47907 - Tel (317) 749-2533)*

30-May 2 Environmental Sciences Meeting, [IES] Seattle, WA *(Dr. Amiram Roffman, Energy Impact Assoc., Inc., P.O. Box 1899, Pittsburgh, PA 15230 - Tel. (412) 256-5640)*

30-May 3 1979 Offshore Technology Conference, [ASME] Astrohall, Houston, TX *(ASME Hq.)*

MAY 1979

7-10 Design Engineering Conference & Show, [ASME] McCormick Place, Chicago, IL *(ASME Hq.)*

20-25 Spring Meeting and Exposition, [SESA] San Francisco, CA *(SESA, 21 Bridge Square, P.O. Box 277, Saugatuck Sta., Westport, CT 06880 - Tel. (203) 227-0829)*

JUNE 1979

12-16 Acoustical Society of America, Spring Meeting, [ASA] Cambridge, MA *(ASA Hq.)*

18-20 Applied Mechanics, Fluid Engineering and Bioengineering Conference, [ASME-CSME] Niagra Hilton Hotel, Niagra Falls, NY *(ASME Hq.)*

JULY 1979

9-13 5th World Congress on the Theory of Machines and Mechanisms, [ASME] Montreal, Quebec, Canada *(ASME Hq.)*

SEPTEMBER 1979

10-12 ASME Vibrations Conference, [ASME] St. Louis, MO., *(ASME Hq.)*

10-13 Off-Highway Meeting and Exposition, [SAE] MECCA, Milwaukee, WI *(SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096)*

11-14 INTER-NOISE 79, [INCE] Warsaw, Poland, *(INTER-NOISE 79, IPPT PAN, ul. Swietokrzyska 21, 00-049 Warsaw, Poland)*

OCTOBER 1979

7-11 Fall Meeting and Workshops, [SESA] Mason, OH *(SESA, 21 Bridge Square, P.O. Box 277, Saugatuck Sta., Westport, CT 06880 - Tel. (203) 227-0829)*

16-18 50th Shock and Vibration Symposium, Colorado Springs, CO *(H.C. Pusey, Director, The Shock and Vibration Information Center, Code 8404, Naval Research Lab., Washington, D.C. 20375 - Tel (202) 767-3306)*

16-18 Joint Lubrication Conference, [ASLE-ASME] Dayton, OH *(ASME Hq.)*

NOVEMBER 1979

4-6 Diesel and Gas Engine Power Technical Conference, San Antonio, TX *(ASME Hq.)*

5-8 Truck Meeting, [SAE] Marriott, Ft. Wayne, IN *(SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096)*

26-30 Acoustical Society of America, Fall Meeting, [ASA] Salt Lake City, UT *(ASA Hq.)*

DECEMBER 1979

2-7 Winter Annual Meeting, [ASME] Statler Hilton, New York, NY *(ASME Hq.)*

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS: American Federation of Information Processing Societies
210 Summit Ave., Montvale, NJ 07645

AGMA: American Gear Manufacturers Association
1330 Mass. Ave., N.W.
Washington, D.C.

AHS: American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA: American Institute of Aeronautics and Astronautics, 1290 Sixth Ave.
New York, NY 10019

AIChE: American Institute of Chemical Engineers
345 E. 47th St.
New York, NY 10017

AREA: American Railway Engineering Association
59 E. Van Buren St.
Chicago, IL 60605

AHS: American Helicopter Society
30 E. 42nd St.
New York, NY 10017

ARPA: Advanced Research Projects Agency

ASA: Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE: American Society of Civil Engineers
345 E. 45th St.
New York, NY 10017

ASME: American Society of Mechanical Engineers
345 E. 45th St.
New York, NY 10017

ASNT: American Society for Nondestructive Testing
914 Chicago Ave.
Evanston, IL 60202

ASQC: American Society for Quality Control
161 W. Wisconsin Ave.
Milwaukee, WI 53203

ASTM: American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

CCCAM: Chairman, c/o Dept. ME, Univ. Toronto,
Toronto 5, Ontario, Canada

ICF: International Congress on Fracture
Tohoku Univ.
Sendai, Japan

IEEE: Institute of Electrical and Electronics Engineers
345 E. 47th St.
New York, NY 10017

IES: Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IFToMM: International Federation for Theory of Machines and Mechanisms, U.S. Council for TMM, c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE: Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA: Instrument Society of America
400 Stanwix St.
Pittsburgh, PA 15222

ONR: Office of Naval Research
Code 40084, Dept. Navy
Arlington, VA 22217

SAE: Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096

SEE: Society of Environmental Engineers
6 Conduit St.
London W1R 9TG, UK

SESA: Society for Experimental Stress Analysis
21 Bridge Sq.
Westport, CT 06880

SNAME: Society of Naval Architects and Marine Engineers, 74 Trinity Pl.
New York, NY 10006

SPE: Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC: Shock and Vibration Information Center
Naval Research Lab., Code 8404
Washington, D.C. 20375

URSI-USNC: International Union of Radio Science - US National Committee c/o MIT Lincoln Lab.,
Lexington, MA 02173

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